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Sophus von Rosen

On May 31 1965 *Sophus von Rosen* will retire as head of the Lund University Department of Orthopaedics at Malmo General Hospital This issue of Acta Orthopaedica Scandinavica contains contributions from his past and present staff members who honor him on this occasion

Sophus is an eminently contemporary individual his career therefore provides an unusual record of key developments in our speciality Indeed even before the beginning of his professional curriculum his activities should inspire envy in today s objects of the graduation machine Sophus matriculated as a student at Lund University in 1917 and he graduated from the Medical School in 1928 In those days the University of Lund was a center of turbulent activities in both the cultural and political spheres Sophus contributed to these activities with his graceful presence and delightful wit He achieved more than temporary fame as a classic in the art of students skits His best known parts were Erik XIV a Swedish dictator king who was poisoned by his brother and Nero the emperor (Fig 1) In real life he has never re enacted these roles Five years after graduation he was appointed head of an Orthopaedic Department in Harnosand the first in the entire north of Sweden and in 1940 he was appointed to his present position in Malmo Throughout his 32 years as a head of clinical departments Sophus has accumulated an outstanding record as a loyal friend of his younger colleagues

Sophus wrote his thesis in 1939 on a subject which is relatively unknown to todays orthopaedists Die Infektiosen Krankheitsprozesse der Kniescheibe These studies focused his interest on the knee region he became an enthusiast for patellectomy following fracture of the patella or in degenerative osteoarthritis of the knee joint and advocated wedge osteotomy of the tibia in varus or valgus types of the latter condition he wrote the chapter on the knee joint in the Scandinavian Textbook of Orthopaedics in 1959



Fig 1
Sophus April 30 1924

In 1956 Sophus published his first article on early diagnosis and treatment of congenital dislocation of the hip joint based on a study begun in 1952 In 1965 he could report on findings in more than 30 000 newborns (Fig 2) During less than 10 years our concepts of this classic orthopaedic disease had radically changed from preoccupation with treatment to emphasis on the multifactorial etiology and on prevention Sophus recognized early that this revolution in thought would occur too slowly unless spurred by an intensive propaganda drive he has talked on congenital dislocation of the hip in Africa India Japan U S A Canada and in most European countries (Fig 3)

Throughout this decade of intensive concentration on one subject and recognizing that he was engaged in a massive prospective clinical experiment Sophus retained a remarkable interest in a diversity of orthopaedic problems His intuition and generally conservative approach prevented his department from becoming involved in the initial indiscriminate adoption of the acrylic hip prosthesis On the other hand he showed early interest in the valgus osteotomy and the hanging hip



Fig 2
Sophus 1965

procedure for coxarthrosis and he participated with a succession of senior residents in developing an eclectic attitude toward management of the increasingly heavy load of trauma in his department

Sophus has had marked success in fostering an attitude of enquiry in his junior staff members In a very real sense he has himself consistently approached the individual patient as a unique problem he has therefore always been active in helping younger colleagues to start clinical or more basic investigations Sophus has always stressed that research is immediately beneficial to the patients studied sometimes directly and always indirectly because the practice of medicine requires an intellectual attitude Few have demonstrated this principle better than he did when congenital dislocation of the hip this classic ortho-

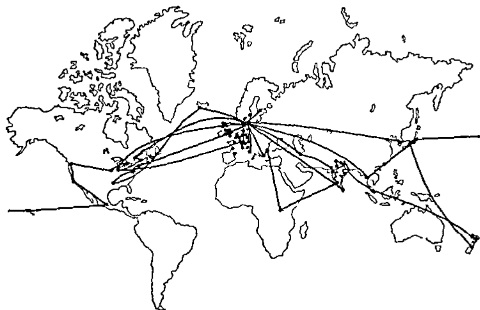


Fig 3
Campaigning for early diagnosis and treatment of congenital dislocation of the hip

paedic condition was virtually eradicated as a cause of life long disability in the region where he works

In his training of residents, Sophus has consistently advocated the necessity for team work within his department and co operation within the hospital and with the outside world He has placed less emphasis on the dogmatic aspects of training but rather has excelled in the early recognition of talent and has delegated responsibility to a degree un usual in a senior clinician The reason for this policy can be traced to his own experience as regards management of orthopaedic conditions Antibiotics hip fracture nailing and intervertebral disc surgery were unknown when he trained and were standard one decade later During the next decade tuberculosis and haematogenous osteomyelitis all but disappeared and in the 1960 s polio was prevented possibly for good The growth of his own department (Table) reflects the increase in traumatic cases and co operation with other medical specialities In his formal training of residents Sophus has thus emphasized how to day s therapy at best represents temporary solutions of fundamental problems

As an organization man Sophus has characteristically favored the informal impromptu approach He was founder of the Swedish Ortho

paedic Society of which he is now an honorary member and he has edited Acta Orthopaedica Scandinavica in his own home since 1950 Sophus gentle authority and kind wit have contributed an important feature to organizations in which he is an active member his department is unique in the ease with which staff members can communicate with him and therefore with each other

The Orthopaedic Department in Malmo—Then and Now

	1941	*1964*
Number of beds	46	156
Patients admitted	358	1 779
Operations on patients admitted	153	1 323
Wards	1	5
Clinic Visits	?	37 500
Operations in ambulatory patients	201	1 197
Staff Surgeons	2	9
Registered Nurses	3	22
Physical Therapists	0	7
Secretaries	0	7
Total number of employees	?	150

Sophus still runs up the stairs in the Old Orthopaedic Building in Malmo and he is as sensitive as ever to a wind of change We can expect therefore that he will be busy during the next period of his life and we wish him succes whether he will decide to stay home or perhaps continue his career abroad

New York City April 1965

GORAN C H BAUER

SOPHUS VON ROSEN

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EXTERNAL COUNTING OF ^{85}Sr AND ^{47}Ca IN LOCALIZED BONE INFECTIONS

By

JOHN FREDRIK DYMLING and BO WENDEBERG

INTRODUCTION

In 1959 *Bauer & Wendeberg* reported external counting over various localized bone lesions after administration of bone seeking γ emitting isotopes. Since that time several reports have been published dealing with isotope studies of skeletal metabolic response to fracture (*Wendeberg* 1961), tumour (*Gynning et al.* 1961, *Corey et al.* 1962, 1963, *Wendeberg & Yamamuro* 1965), coxarthrosis (*Danielsson, Dymling & Hernborg* 1964) and infectious disease of the spine (*Lindberg & Fellander* 1965). This is a report on external counting of ^{85}Sr and ^{47}Ca over localized bone infections in the extremities.

METHODS

Carrier free ^{47}Ca (half life 4.9 days) or ^{85}Sr (half life 65 days) were used. The isotope was given as a single rapid intravenous injection. External counting was performed usually 168 and 336 hours after injection over the diseased part of the skeleton, over the contralateral side and over the knees and thighs (*Bauer & Wendeberg* 1959). A 12 wide angle collimator placed in contact with the skin over the area to be counted was routinely used. When the opening of this collimator was considered to be too large, a cylindric collimator with an opening of 24 mm was used. This was especially the case in children. For specific purposes a 10 mm slot collimator was used.

Financial support was obtained from grants to *Göran C. H. Bauer* from the *International Atomic Energy Agency* and *United States Public Health Service* Grant D-1459.

The maximal dose administered was 1 μC per kilogram of body weight or 50 μC. The amount of radiation delivered to the skeleton by this dose was calculated to be less than the maximal permissible dose recommended by the International Comission on Radiological Protection (*Bauer & Wendeberg* 1959).

The results were expressed as *activity ratios* or *activity*.

Activity was expressed as per cent of a standard solution of ^{85}Sr or ^{47}Ca in order to account for the physical decay. The ratio was taken between the diseased part of the skeleton and the contralateral side. Normally activity ratio is close to unity. *Danielsson, Dymling & Heripret* (1963) calculated the activity ratios between normal knees and found 1.00 ± 0.018 and between identical parts of the tibiae and found 1.03 ± 0.018.

MATERIAL

The clinical material consisted of 25 patients: 12 with active septic osteomyelitis, one with active septic coxitis, five with non active septic osteomyelitis, three with active tuberculous osteomyelitis, one with active tuberculous coxitis, two with non active tuberculous osteomyelitis and one with non active tuberculous gonitis.

The term osteomyelitis was defined to mean infectious disease involving bone caused by staphylococci, streptococci or tubercle bacilli. Infections caused by staphylococci and streptococci were called septic. The roentgenologic evaluation[1] was based on skeletal roentgenograms of the diseased part at the time of investigation and later in the course of the disease.

The diagnosis was established on the basis of clinical findings, findings at surgery when performed, bacteriologic and roentgenologic findings. The time of observation after the study varied from 6 months to 7 years.

The cases of active septic osteomyelitis involved the calcaneus in three cases (C 87, C 96, D 83), the tibia in three cases (A 22, E 109, H 57), the femur in two cases (F 33, F 83), the humerus in two cases (A 31, B 15) and the ulna in one case (H 56). In one case there was involvement of the knee joint (B 39) and another case (H 55) was a coxitis caused by staphylococci. 15 studies were performed.

The five cases of non active septic osteomyelitis involved the tibia in two cases (F 102, H 17) and the femur in three cases (F 72, G 35, H 56).

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[1] The roentgenologic evaluation was kindly carried out by *Lars Andrén*, M.D., of the Department of Roentgenology, General Hospital, Malmo.

In three of these (F-72 F 102 G 35) the inflammatory activity in the infectious process was questionable at the time of tracer study but continued observation during 2 2 and 1½ years respectively established the diagnosis

The four cases of active tuberculous infection involved the trochanteric region in two cases (B 6 B 94) and the ulna in one case (H 58) One case (H 52) was a tuberculous coxitis The non active tuberculous processes were localized in the trochanteric region in one case (H 23) in the hipjoint in one case (H 71) and in the kneejoint in one case (H 9) One study was performed in each of these cases Pertinent data are found in Table 1

RESULTS

The activity ratios 14 days after injection were plotted against the duration of clinical symptoms in the active cases (Fig 1) The activity ratios were found to increase above normal after an initial lag period of approximately 14 days

The activity ratios 14 days after injection were better separated than those 7 days after injection (Fig 2) The cases that were injected during the lag period have been indicated with open circles in Fig 2 If the cases are excluded the activity ratios in active bone infections were above 2 2 and in non active bone infections below 1 5

The results of the roentgenologic examination at the time of study

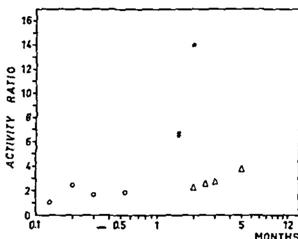


Fig 1

Activity ratios 14 days after injection of ^{47}Ca or ^{85}Sr Circles indicate septic infections and triangles tuberculous infections

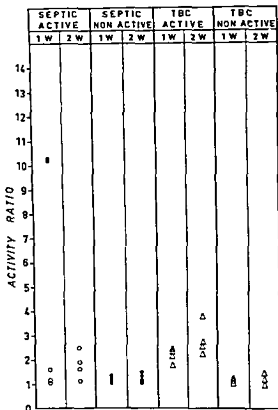


Fig 2
Activity ratios 7 and 14 days after injection of ^{4}Ca or ^{85}Sr

varied (Table 1) but in the following cases no definite signs of active bone infection could be found A 22 B 39 C 87 C-96 D 83 F 109 F-83 H 57 in the septic group and B 94 in the tuberculous group Later in the course of the disease all acute cases developed roentgenologic evidence of bone involvement and the recurrent cases showed changes in the skeletal roentgenograms

CASE HISTORY

Case F 83 is illustrative and will be reviewed The patient was a 42 year old engineer admitted to the orthopaedic clinic in May 1962 with a complaint of intermittant predominantly nocturnal pain in the area of his right knee of five years duration He had no known focus of infection however in 1957 he had acute cystitis at which time he was cystoscoped Clinical investigation and skeletal roentgenogram showed no evidence of intra or extra articular disease E.S.R was 4 mm/hr Femoral angiography was normal Isotope study demonstrated a localized

Septic Active

Code No	A-22	A-22	A-31	B-15
Age (years)	6	6	29	66
Sex	M	M	M	M
Occupation	–	–	Factory foreman	Factory worker
Weight (kg)				80
Diagnosis	Osteomyelitis tibia dx acuta	Idem	Osteomyelitis humeri dx recidivans	Osteomyelitis humeri dx acuta
Roentgenogram at time of isotope study	0	0	Large osteolytic focus with surrounding sclerosis and small sequestration	Osteolytic focus with periosteal reaction
Duration of symptoms d=days w=weeks	4 d	22 d	50 w	6 w
Isotope	^{85}Sr	^{85}Sr	^{85}Sr	^{85}Sr
Dose μC	7	11	35	45
Ratio 24 h	–	–	2 48 (72 h)	4 8 (72 h)
168 h	1 15	4 69 (120 h)	10 3 (192 h)	–
336 h	1 10	3 92 (480 h)	14 3	6 76 (360 h)

Septic Active

Code No	E-109	F-33	F-83
Age (years)	6	39	42
Sex	M	M	M
Occupation	–	Seaman	Engineer
Weight (kg)		65	80
Diagnosis	Osteomyelitis tibiae sin acuta	Osteomyelitis femor dx acuta	Osteomyelitis femor dx
Roentgenogram at time of isotope study	0	Osteolytic focus with periosteal reaction	Insignificant slight increase in thickness of cortex
Duration of symptoms d=days w=weeks	6 d	6 w	18 w
Isotope	^{85}Sr	^{85}Sr	^{85}Sr
Dose μC	20	50	45
Ratio 24 h	–	–	–
168 h	1 88	6 9	1 86
336 h	2 48	6 6	3 00

B–39	C–87	C–96	D–83
38	14	14	10
M	M	F	F
Officeworker	–	–	–
49		58	44
Osteomyelitis femor dx cum gonitis recidivans	Osteomyelitis calcan dx acuta	Osteomyelitis calcan dx acuta	Osteomyelitis calcan dx acuta
Old osteomyelitis in lower femur with reactive changes in bone Deformed joint in valgus position	0	0	0
5 w	1 d	9 d	16 d
^{85}Sr	^{85}Sr	^{85}Sr	^{85}Sr
50	20	20	15
	–	–	–
7 20 (192 h)	1 09 (120 h)	1 62	1 41 (96 h)
9 80	–	1 63 (188 h)	1 87

F 83	H 55	H–56	H–57
42	19	44	41
M	M	M	M
	Soldier	Engineer	Furrier
47	77	76	6
	Coxitis dx acuta	Osteomyelitis ulnae dx recidivans	Osteomyelitis tibiae dx recidivans
Idem	Periacetabular osteopenia and reduced cartilage	2 large osteolytic foci	Irregular structure with sclerosis and thickening of tibia
50 w	8 w	8 w	3 w
^{85}Sr	^{85}Sr	^{85}Sr	^{85}Sr
75	50	50	50
	–	–	–
3 33	4 07	10.2	5 63
4.30	4 29	14 0	5 10

Septic Active

Code No	A-2?	A-22	A-31	B-15
Age (years)	6	6	29	66
Sex	M	M	M	M
Occupation	–	–	Factory foreman	Factory worker
Weight (kg)				80
Diagnosis	Osteomyelitis tibia dx acuta	Idem	Osteomyelitis humeri dx recidivans	Osteomyelitis humeri dx acuta
Roentgenogram at time of isotope study	0	0	Large osteolytic focus with surrounding sclerosis and small sequestration	Osteolytic focus with periosteal reaction
Duration of symptoms d=days w=weeks	4 d	22 d	50 w	6 w
Isotope	^{85}Sr	^{85}Sr	^{85}Sr	^{85}Sr
Dose μC	7	11	35	45
Ratio 24 h	–	–	2 48 (72 h)	4 8 (72 h)
168 h	1 15	4 69 (120 h)	10 3 (192 h)	–
336 h	1 10	3 92 (480 h)	14 3	6 76 (360 h)

eptic Active

No	E-109	F-33	F-83
(years)	6	39	42
	M	M	M
Occupation	–	Seaman	Engineer
Weight (kg)		65	80
Diagnosis	Osteomyelitis tibiae sin acuta	Osteomyelitis femor dx acuta	Osteomyelitis femor dx
Roentgenogram at time of isotope study	0	Osteolytic focus with periosteal reaction	Insignificant slight increase in thickness of cortex
Duration of symptoms d=days w=weeks	6 d	6 w	18 w
Isotope	^{85}Sr	^{85}Sr	^{8} Sr
Dose μC	20	50	45
Ratio 24 h	–	–	–
168 h	1 88	6 9	1 86
336 h	2 48	6 6	3 00

The Active

Code Nr	B 6	B-34	H-52	H-58
Age (years)	56	41	52	29
Sex	M	F	M	M
Occupation	Factoryworker	Housewife	Factoryworker	Truckdriver
Weight (kg)	50	57	61	80
Diagnosis	Osteomyelitis the troch sin recidiv	Osteomyelitis the troch dx recidiv	Coxitis the dx recidiv	Osteomyelitis the ulnae sin
Roentgenogram at time of isotope study	Irregular structure with progressive bone and joint destruction and sequestration	*Irregular structure* with large postoperative defect No signs of activity	*Progressive changes*	Cystic changes with sequestration
Duration of symptoms d—days w—weeks	12 w	8 w	20 w	10 w
Isotope	^{47}Ca	^{85}Sr	^{85}Sr	^{85}Sr
Dose μC	60	50	50	35
Ratio 24 h	–	–	–	–
168 h	2 35	2 15	1 76	2 38
336 h	2 75	2 24	3 83 H/K 5 45 right H/K 1 71 left	2 57

The Non Active

Code No	H-9	H-23	H-71
Age (years)	31	63	42
Sex	M	F	M
Occupation	Factoryworker	Spinster	Technician
Weight (kg)	61	77	57
Diagnosis	St p gonitis tbc dx	St p osteomyelitis troch sin	St p coxitis tbc dx op
Roentgenogram at time of isotope study	Irregular joint with large usurations and reduced cartilage	Irregular structure with small defect in cortex	Resorption around cup Sclerotic acetabulum
Duration of symptoms d=days w=weeks			
Isotope	^{85}Sr	^{85}Sr	^{85}Sr
Dose μC	50	50	40
Ratio 24 h	–	–	–
168 h	1 15	1 22	1 06
336 h	1 42	1 18	0 96

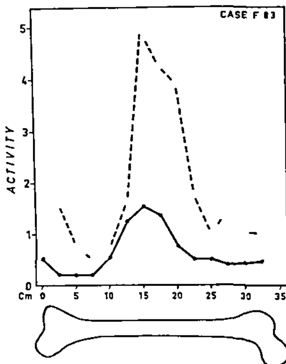


Fig 3

Activity at various locations over the right femur in case F 83 External counting was performed at 2 5 cm intervals with a 10 mm wide slot collimator The continuous line shows the activity obtained in May 1962 and the broken line the activity found in October 1962

area of increased ^{85}Sr uptake 15 cm proximal to the superior border of the patella (Fig 3)

The patient was discharged and after a short symptom free period during the summer the pain returned Repeat roentgenograms in October 1962 including tomography was normal except for an area of slight cortical thickening of the medial aspect of the femoral shaft Repeat isotope study was principally identical to the first (Fig 3)

Operative exploration of the medial aspect of the femoral shaft revealed an area of periosteal hyperemia and softening of the underlaying bone tissue corresponding to the peak of increased ^{85}Sr uptake Biopsy of this area showed histologic signs of chronic osteomyelitis Penicilline was administered Postoperatively the patient has remained almost completely symptom free

DISCUSSION

The increased uptake of bone seeking isotopes found with external counting over localized bone disease is interpreted as a sign of increased

skeletal metabolism or more specifically locally increased accretion rate The easiest way to express this increase is to calculate the ^{8}Sr or ^{4}Ca activity ratio between the diseased part of the skeleton and the contralateral side This requires access to a contralateral side which is possible except for the axial skeleton External counting over the spine may be expressed in different ways (*Gynning et al* 1961 *Bauer & Scoccianti* 1961 *Lindberg & Fellander* 1965) Furthermore the contra lateral side should be normal If the contralateral side is affected by some disease process some other point of reference must be found This is exemplified by case H 52 In this case the right hip was hit by infection and the left by arthrosis This was manifested in an increased hip over knee ratio on both sides (cf *Danielsson Dymling & Heripret* 1963) The hip/hip activity ratio of 3 8 should consequently have been even higher had the left hip been normal Normally the activity ratio is close to unity In cases of old non active osteomyelitis this is not the case This may be due to postinfectious remodelling of the bone and differences of bone mass seen by the detector

Increased activity ratios were not found immediately the symptoms appeared This means that the metabolic response of the bone as a tissue is delayed It is probable that this delay is related to the metabolic turn over rate of the affected bone If this is the case the lag period should vary from bone to bone since the turn over rate varies from bone to bone (*Frost, Villanueva & Roth* 1960) These possible differences can not be evaluated in this series However when the tracer study was started two weeks or more after the symptoms appeared increased activity ratios were obtained in all cases

The optimal time for external counting cannot be exactly assessed but in general external counting performed 14 days after injection is supe rior to external counting performed 7 days after injection The rationale of this is that at 14 days after injection little activity is found in the soft tissues and the exchangeable fraction of bone (*Wendeberg* 1961) and consequently the local accretion is of greater importance The ex perience in our laboratory is that external counting performed 14 days after injection gives reliable informations and is easily arranged both for the patients and the laboratory

In the acute cases it was found that external counting gave evidence of local bone disease at a time when the roentgenograms were still normal This is in accordance with findings in similar studies of bone tumours In chronic cases the question if the infectious process is active or not is notoriously difficult to answer on the basis of roent

genograms. In these cases external counting gave reliable results as far as prolonged clinical observation and repeated roentgenograms are capable of distinguishing this entity. In no case in our series were there roentgenologic or clinical signs of activity and normal external counting. In no case of non active osteomyelitis was the activity ratio above 1.5. In the active cases the ratio 14 days after administration of the isotope was always above 2.2. It is concluded that an activity ratio of 2.0 is a reasonably reliable arbitrary border line with the detector geometry used here. If the clinical findings suggest active bone infection and the symptoms have lasted more than a fortnight before injection of the isotope, an activity ratio above 2.0 strongly supports the clinical diagnosis even if the roentgenograms are normal or do not show any signs of activity.

The case history illustrated that external counting can give evidence of localized bone disease when roentgenograms are questionable or even negative. The tracer data gave the surgeon an exact localization of the disease process; an exploration would not have been undertaken without these data.

SUMMARY

External counting after injection of ^{45}Ca or ^{85}Sr has been performed in 17 cases of active and 8 cases of non active bone or joint infections. Increased uptake of bone seeking radioisotopes were regularly found in areas of active bone infection when the symptoms had lasted for approximately 14 days. Active and non active bone infections could be completely separated by this method.

External counting gave reliable information earlier than roentgenologic investigation in acute cases and was particularly useful as a compliment to roentgenograms in evaluating recurrence of the infectious process in chronic cases.

RESUME

Il a ete procede un comptage externe apres injection de ^{45}Ca ou de ^{85}Sr dans 17 cas d'infections osseuses ou articulaires actives et dans 8 cas non actives. On a regulierement trouve un nombre accru de radio-isotopes recherchant les os dans les regions d'une infection osseuse active lorsque les symptomes avaient dure approximativement 14 jours. Les infections osseuses actives et non actives ont pu etre entierement separees au moyen de cette methode.

Le comptage externe a donné des informations sures plus tot que les

examens radiographiques dans les cas aigus et il a ete particulierement utile comme un complement aux radiogrammes pour evaluer dans les cas chroniques les chances de recurrence du processus infectieux

ZUSAMMENFASSUNG

Externe Zählung nach Injektion von ^{47}Ca oder ^{85}Sr wurde in 17 Fallen von aktiven und in 8 Fallen von nichtactiven Knochen oder Gelenksinfektionen ausgefuhrt Gesteigerte Aufnahme von knochen aufsuchenden Radiumisotopen wurden regelmässig in Gebieten aktiver Knocheninfektion gefunden wenn die Symptome ungefahr 14 Tage bestanden hatten Aktive und nicht aktive Knocheninfektionen konnten auf diese Weise vollständig voneinander getrennt werden

Externe Zahlung gab in akuten Fallen fruhzeitiger verlassliche Auskunft als rontgenologische Untersuchung und war besonders wertvoll als eine Ergänzung der Rontgenuntersuchung bei der Beurteilung von Rezidiven des infektiosen Prozesses in chronischen Fallen

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MINERAL METABOLISM IN PRIMARY BONE TUMORS STUDIED BY EXTERNAL COUNTING OF ^{85}Sr

By

Bo Wendeberg and Takao Yamamuro

INTRODUCTION

Mulry & Dudley (1951) reported increased uptake of Ga in 15 of 18 primary or secondary bone tumors and that skeletal tumor metastasis could be detected by isotope technique before being visible on roentgenograms

Gynning et al (1961) and *Corey et al* (1962) have also shown the advantages of isotope techniques in addition to roentgenography for early detection of bone metastasis

Previous communications have described the technique of body surface activity measurements of intravenously injected ^{47}Ca and ^{85}Sr (*Bauer & Wendeberg* 1959 *Wendeberg* 1961) The results suggested that the method may be valuable for localisation and delineation of bone lesions such as fractures infections and tumors Subsequent reports have been made concerning external counting over fractures (*Wendeberg* 1961) bone infections (*Dymling & Wendeberg* 1965 *Fellander & Lindberg* 1964) and osteoarthritis of the hip (*Danielsson Dymling & Heripret* 1964)

The present report deals with the uptake of intravenously injected ^{85}Sr in primary bone tumors assayed by means of the external counting technique

CASE MATERIAL

The report is based on studies of 22 cases of primary bone tumor osteogenic sarcoma (3 cases) chondrosarcoma (2 cases) eosinofilic granuloma (3 cases) osteoclastoma (4 cases) solitary bone cyst (4 cases) osteofibroma (4 cases) Ewing s sarcoma (1 case) and Letterer

TABL

Case no	Fig no	Age	Sex	Diagnosis	Localisation
I	1 2 3	10	♀	Osteogenic sarcoma	Large tumour destruction of distal lateral femur
II	4 5	13	♀	Osteogenic sarcoma	Large tumour destruction of distal lateral femur
III	6 7	50	♂	Osteogenic sarcoma	Massive tumour involvment around prox femur
IV		57	♀	Chondrosarcoma	Large tumour destruction of th upper part of femoral diaph
V	8 9	45	♂	Chondrosarcoma	Tumour localised to lateral femoral condyle Size 5 × 5 × 4 cm
VI	10 11	3	♂	Eosinophilic granuloma	Large tumour in the middle p of femur
VII		12	♂	Eosinophilic granuloma	Tumour localised to the diaphysis of humerus
VIII		9	♀	Eosinophilic granuloma	Rather large destruction of pro tibia
IX		16	♀	Osteoclastoma	Large destruction of caput humeri
X		48	♀	Osteoclastoma	Large destruction of distal fem
XI		55	♀	Osteoclastoma	Large destruction of caput humeri
XII	12 13	23	o	Osteoclastoma	Total destruction and compre sion of vertebral body L III
XIII		6	♂	Solitary bone cyst	Large cyst in trochanteric reg of femur
XIV		11	♂	Solitary bone cyst	Large cyst in prox humerus
XV		10	♀	Solitary bone cyst	Small cyst in prox fibula
XVI		17	♂	Solitary bone cyst	Small cyst in distal humerus
XVII		11	♂	Osteofibroma	Small fibroma in distal femur
XVIII		18	♀	Osteofibroma	Small fibroma in prox tibia Size 1 × 1 × 2 cm

e µC	Collimato	Inte val ft r inject o	Acti ity ratio	C mments
25	12	2 days	7 6	Act measurem on bone spec.
	12	20 days	7 3	post mortem
50				
50	10 mm	20 hours		Amputation
50	12	7 days	5 8	
	12	14 days	7 5	
50	12	7 days	11 9	
	12	14 days	12 1	
50	12	5 days	7 3	See *Bauer Wendeberg* 1959
	12	14 days	11 0	Case 9
50	12	9 days	11 4	
	12	14 days	11 7	
50	12	9 days	11 0	
	12	14 days	12 6	
50	12	7 days	8 6	
15	24 mm	5 days	9 3	
	24 mm	10 days	9 4	
30	24 mm	7 days	6 3	
	24 mm	12 days	4 8	
20	12	6 days	11 2	See *Bauer Wendeberg* 1959 Case 10
30	12	14 days	2 2	
50	12	10 days	3 9	
40	12	7 days	4 3	
	12	14 days	4 1	
35	12	7 days		Marked activity
		14 days		peak over bone lesion
20	12	11 days	1 8	See *Bauer Wendeberg* 1959
	12	18 days	1 8	Case 11
30	12	14 days	3 7	
30	12	7 days	1 1	
	12	14 days	1 0	
30	12	7 days	1 0	
	12	14 days	1 0	
30	12	7 days	1 2	
	12	14 days	1 2	
35	12	7 days	1 2	
	12	14 days	1 2	

TABLE

Case no	Fig no	Age	Sex	Diagnosis	Localisation
XIX		13	♂	Osteofibroma	Fibroma of distal tibia Size 2 × 2 × 4 5 cm
XX		12	♀	Osteofibroma	Small fibroma of distal tibia. Size 1 × 1 × 2 5 cm
XXI		9	♀	Ewing s sarcoma	Tumour localized to lumbo sacral region of the spine
XXII	14a+b	2	♀	Letterer Siwe s disease	Large bone destruction of prox. tibia and prox femur

Siwe s disease (1 case) Patient age ranged from 2 to 55 years The diagnoses were based on clinical appearance roentgenography and in most cases microscopy of biopsy specimens The localisation and relative size of the tumors with other pertinent data of the patients are given in Table 1 The case numbers used in the text refer to this table

METHOD

The patients were given less than 1 μC carrierfree ^{85}Sr per kilogram body weight by intravenous injection External counting was performed with a collimated scintillation detector Three sets of collimators were alternatively used a 12 wide angle collimator a 24 mm cylindrical collimator and a 10 mm slot aperture collimator The positioning of the detector in relation to the bone lesion was made with the aid of roent genograms and palpation The collimator was placed with its outer aperture close to the skin over the area to be counted The activity measurements were made at irregular time intervals after injection of ^{85}Sr usually at about 1 and 2 weeks For further details of the method see *Bauer & Wendeberg* (1959)

The results were when possible expressed as *activity ratio i e* counting rate over bone tumor to counting rate over corresponding normal bone In two cases of tumors of the spine the activity values were compared to activity values of normal persons (*Bauer & Scoccianti* 1961) Absolute activity measurements were made in a well crystal scintillation counter on bone ash dissolved in concentrated nitric acid and were expressed as per cent of dose per gram ash weight

ont)

e µC	Collimator	Interval after injection	Activity ratio	Comments
15	12	6 days	2 0	
10	24 mm	4 days	1 9	
	12	4 days	1 3	
15	12	7 days		Slightly increased activity compared to normal values
		14 days		
10	12	14 days		
		tibia	0 5	
		femur	0 8	

RESULTS

The three cases of osteogenic sarcoma all showed significantly higher uptake of ⁸ Sr in the tumor area than in corresponding normal bone tissue (Figs 1 2 4 6) The activity ratios 14 days after injection were

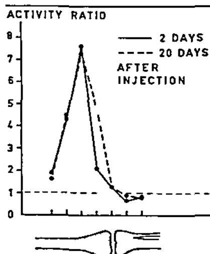


Fig 1

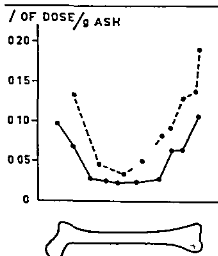


Fig 2

Fig 1 Case 1 Osteogenic sarcoma of distal femur The roentgenogram is given in Fig 3

Fig 2 Case I Osteogenic sarcoma of distal femur 50 µC of ⁸ Sr was given 2 days before the patient died of pulmonary metastasis Graph shows absolute activities expressed as per cent of dose gm ash weight in bone specimens taken from tumor femur (-----) and normal femur (———)

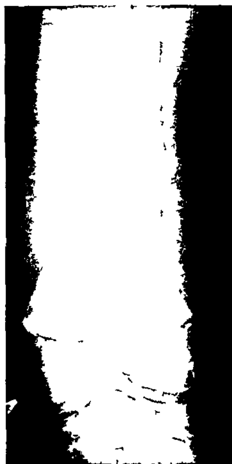


Fig 3
Case I Osteogenic sarcoma

found to be as high as 12 in case III where the ratio increased from 7.5 to 12 1 during the four month interval between the two investigations performed in this case (Fig 6) Activity measurements were made on bone ash from the affected and the normal femur of case I who was given a second injection of ^{85}Sr two days before she died from pulmonary metastasis In all bone specimens taken from the affected femur in this case the activity per gram ash weight was higher than the activity of corresponding specimens from the normal femur (Fig 2) In case II measurements were made with the 10 mm slot aperture collimator over the bone specimen dissected free from soft tissues after thigh amputation The activity curve given in Fig 4 shows the delinea

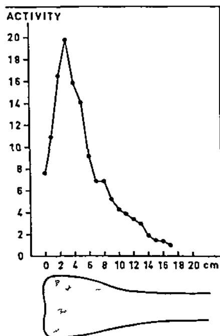


Fig 4



Fig 5

Fig 4 Case II Osteogenic sarcoma of distal femur Thigh amputation was performed 20 hours after isotope injection The distal femur was dissected free from soft tissues Activity measurements were made with a 10 mm slot aperture collimator The roentgenogram of the tumor is given in Fig 5

Fig 5 Case II Osteogenic sarcoma

tion of the tumor in the distal femur and will be compared to the roentgenographically visualized tumor of Fig 5

In the cases of the chondrosarcomas (Fig 8 and case 9 in *Bauer & Wendeberg* 1959) the eosinofilic granulomas (Fig 10) and the osteoclastomas (Fig 12) the activity ratios were significantly higher than normal This was true even in those cases of osteoclastoma where bone destruction was advanced

In the series of solitary bone cysts and osteofibromas the activity ratios varied In some cases the ratios approximated 1 but were in others significantly higher The higher values were found in cases with relatively large cysts or fibromas

The case of Ewing s sarcoma of the spine was found to have slightly increased activity uptake over the tumor area compared to normal cases In the case of Letterer Siwe s disease the activity ratio was lower

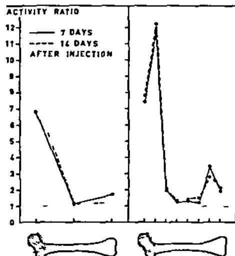


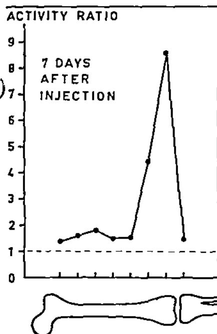


Fig 6

Fig 7

Fig 6 Case III Osteogenic sarcoma of proximal femur The first investigation (left) was made four months prior to the second (right) The roentgenogram is given in Fig 7

Fig 7 Case III Osteogenic sarcoma



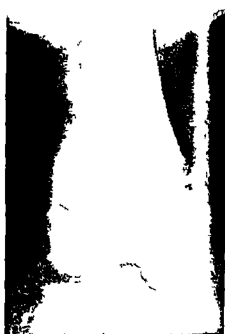


Fig 8

Fig 9

Fig 8 Case V Chondrosarcoma of distal femur The roentgenogram is given in Fig 9

Fig 9 Case V Chondrosarcoma

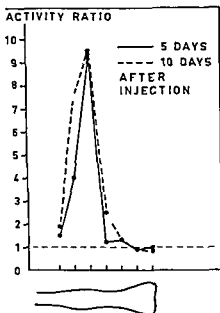


Fig 10
Case VI Eosinophilic granuloma of middle femur The roentgenogram is given in Fig 11



Fig 11
Case VI Eeosinophilic granuloma

than normal over the affected areas of the hip and knee despite evidence of periostal reaction on roentgenogram (Figs 14 a and b)

DISCUSSION

The validity of the external counting method for differentiating bone lesions is limited because skeletal reaction to various lesions (tumor infection or fracture) is non specific and because of certain technical difficulties

Increased uptake of bone seeking isotopes in a localised bone lesion is presumptive evidence of increased bone formation rate The activity observed by the external counting method represents values based on integration of activity present in tumor in bone reacting to tumor and in bone not reacting to tumor since the limits of these three sources

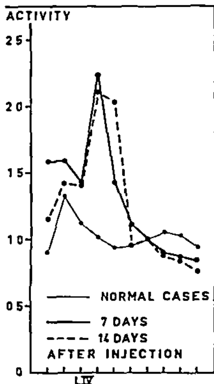


Fig 12
Case XII Osteoclastoma with destruction and compression of the body of L III Normal cases represent values obtained by *Bauer & Scoccianti* (1961) The roentgenogram is given in Fig 13

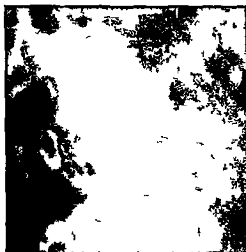


Fig 13
Case XII Osteoclastoma

cannot be defined The bone structure itself of a tumor area is also qualitatively and quantitatively different from normal bone tissue

The activity ratios do not express *absolute* indices but may under standardized conditions (of time intervals and collimators) be used as *relative* indices of differential of bone formation rates in a tumor area compared with normal bone tissue The measurements must be taken when most of the tracer has left soft tissues and body fluids by excretion or incorporation in skeleton Earlier studies from this laboratory suggest that for this purpose 1–2 weeks after injection constitutes a suitable interval and therefore most of the measurements reported here were done within these time limits Furthermore a definitive ratio between the size of the tumor and the aperture of the collimator must be established before valid comparations of activity data from patients




Fig 14 a *Fig 14 b*

Fig 14a Case XXII Letterer Siwe's disease Large tumor destructions of the proximal part of tibia and femur (Fig 14b)

Fig 14b Case XXII See legend of Fig 14a

with different kinds of tumors of varying sizes can be made The areas "seen" by the detector must contain comparable proportions of tumor tissue bone reacting to tumor and bone not reacting to tumor in the different patients Otherwise when using a large aperture collimator for measurements of small tumors for example a large portion of low specific activity bone not reacting to tumor will dilute the minor portion of high specific activity bone reacting to tumor The activity ratio in such a case will be lower than if a more "close" collimation was used (compare activity ratios obtained with 12 wide angle and 24 mm cylindrical collimator in case XX) From a practical point of view such individual collimation cannot be performed The choice of aperture of the collimator used in this study constitutes a compromise between a very wide aperture and a very narrow one

In the series presented here the tumors were of varying sizes The largest tumors were the osteogenic sarcomas the chondrosarcomas the eosinophilic granulomas and the osteoclastomas These tumors also produced the highest activity ratios In some cases of small bone cysts and osteofibromas the activity ratios were slightly above normal while in others they were normal These differences in activity ratios between large and small tumors must not be interpreted as varying bone formation rate in different kinds of tumor but may be caused by unsuitable collimation In the case of Letterer Siwe's disease with extensive bone

destructions of the proximal tibia and the proximal femur in one extremity the activity ratio was lower than normal despite roentgenological evidence of periosteal reactions This may have been due to differences in bone mass of the two extremities

The technique used in this investigation does not distinguish tracer in bone from tracer in tumor *Corey et al* (1961) have presented autoradiographic evidence that in osteogenic sarcomas the tumor itself may incorporate tracer calcium or strontium On the other hand they also found that skeletal metastasis of mammary carcinoma do not incorporate tracer calcium in tumor tissue but only in adjacent bone Hence the increased rate of bone formation observed by external counting over bone tumors without osteogenic properties is not a measure of tumor activity *per se* but rather of a skeletal repair reaction to bone destruction The method thus does not seem to be applicable to differentiating different types of tumor

In case II (Fig 6) activity ratios higher than unity was found throughout the involved extremity The peak activity ratio corresponds to the location of the osteogenic sarcoma in the proximal femur Another minor peak was found over the ipsilateral knee region This latter peak did not reflect tumor involvment but probably a phenomenon observed by *Wendeberg* (1961) in tracer studies of fractures of the shaft of the tibia *i e* increased bone formation distal and proximal to a skeletal lesion in the extremities This reaction which is especially pronounced in metaphyseal bone apparently involves the entire extremity and should not be confused with the area of tumor involvment

Attempts were made to correlate the degree of roentgenologically evident periostial reaction and sclerosis to the activity ratios but no conclusive results were obtained

SUMMARY

The external counting studies of primary bone tumors have shown increased uptake of ^{85}Sr in the tumor area indicating increased bone formation rate probably representing adjacent skeletal reaction to tumor bone destruction The external counting technique seems to give no further information concerning differential diagnosis of bone tumors already visible on roentgenograms Yet as has been shown previously the technique lends itself to early detection of bone lesions as tumor or infection not visible or questionable on roentgenograms The extent of a tumor involvment may be estimated by scanning over the lesions

RESUME

Les etudes par comptage externe des tumeurs osseuses primaires ont montre un accroissement de ^{85}Sr dans la region de la tumeur indiquant un taux accru de formation osseuse representant probablement une reaction squelettique adjacente a la destruction osseuse provoquee par la tumeur La technique du comptage externe ne semble pas donner de plus amples renseignements concernant le diagnostic differentiel des tumeurs ossesusses deja visibles sur les radiogrammes Comme on l a demontre anterieurement cette technique tend en soi a une detection precoce des lesions osseuses comme les tumeurs ou les infections qui ne sont pas visibles ou qui douteuses sur les radiogrammes L etendue d une tumeur doit etre etablie par l examen des lesions

ZUSAMMENFASSUNG

Die externen Zählungsstudien von primären Knochentumoren haben eine gesteigerte Aufnahme von ^{85}Sr in der Tumorregion aufgewiesen und damit eine Steigerung der Geschwindigkeit der Knochenneubildung angezeigt die wahrscheinlich eine Reaktion des angrenzenden Skelettes gegenüber der Knochendestruktion des Tumors darstellt Die externe Zählungstechnik gibt anscheinend keine weitere Auskunft hinsichtlich der Differentialdiagnose von Tumoren die bereits im Röntgenbilde sichtbar sind Wie jedoch fruher gezeigt wurde ist die Technik behilf lich bei der fruhzeitigen Entdeckung von Knochenschäden wie z Bsp Tumoren oder Infektionen die in Rontgenbilde entweder nicht sichtbar sind oder fragwurdig erscheinen Das Ausmass der Tumorausbreitung kann mittels Szintigraphie über der Erkrankungsstelle geschatzt werden

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ARTHROGRAPHY AND MANIPULATION IN RIGIDITY OF THE SHOULDER JOINT

By

Bo J Lundberg

Rigidity of the shoulder joint may be the predominant symptom in humeroscapular periarthritis Within this heterogeneous group the nomenclature distinguishes the true "frozen shoulder

In cases of existing rigidity the limitation of the mobility may be forced by manipulation Ever since this form of treatment was intro duced by *Duplay* (1872) its value has been doubted For various reasons it is difficult to asses its therapeutic effect

The arthrographic findings in rigidity of the shoulder joint have been described by *Bateman* (1955) and in more detail by *de Se e* (1961) The changes appear to consist in obliteration of the articular recesses *Neviaser* (1962) has published arthrograms of two manipulated frozen shoulders in which the contrast medium escaped through tears at the site of the obliterated medial axillary fold At arthrography two months later when mobility had been re established the joint was of a normal appearance That healing of capsular damage due to traumatic dis location of the shoulder joint may occur in 1–4 weeks has been de monstrated arthrographically by *Pettersson* (1942)

Mainly on *Neviaser* s (1945) investigations of exposed rigid shoulders the anatomical basis of the rigidity has been considered a thickened synovial capsule *Neviaser* suggested the term "adhesive capsulitis According to *Bosworth* (1940) and *Wahren* (1942) the limitation of movements was supposed to be due to adhesions within the sub acromial and the subdeltoid bursa respectively *Lippman* (1941) stated that the same would result from adhesions to the biceps tendon especially in its intraarticular course *Lidström* (1963) found that firm

adhesions beneath the coracoid process and in the subacromial space were in most cases the main cause of the rigidity Although preoperative arthrograms showed pronounced tightness of the capsule with partial obliteration of the medial axillary fold he considered the adhesions within the articular recesses to be of subordinate importance On the other hand, *de Seze*, on the basis of the above mentioned arthrographic studies (1961) and also of autopsied cases of shoulder rigidity (1960) feels that the anatomical basis of rigid shoulders is merely retraction of the joint capsule not tendinitis biceps peritendinitis obliterative bursitis or adhesive capsulitis

DePalma (1954) has reported damage to the subcapsular tendon during manipulation under anaesthesia Although several workers including *Payr* (1931) *McLaughlin* (1961) and *Meulengracht & Schwart* (1952) have their misgivings owing to the risk of damage the method has been preferred by others e g *Klapp* (1916) *Reschke* (1919) *Withers* (1949) *Bloch & Nauta* (1951) and *Charnley* (1959) *Lidstrom* (1963) believed that the increased mobility during manipulation was due rather to rupture of the tissues on the anterior aspect of the joint than to a loosening of the adhesions between the tissue layers This was in his opinion an explanation of the varying results of the manipulative procedure

Thus opinions are divided concerning the anatomical cause of the rigidity What happens in manipulation has not been clearly substantiated and warnings have been sounded that it may damage vital articular structures

These aspects have been elucidated by arthrographic studies on a series of patients with shoulder rigidity of various causes treated by manipulation and reported below However the therapeutic result will not be discussed here

MATERIAL AND METHODS

Manipulation under general anaesthesia has been part of the routine treatment of shoulder rigidity in the Orthopaedic Clinic Jonkoping since 1956 In order to check the effect of the manipulation arthrography was done in a number of cases immediately before the procedure After the manipulative procedure the shoulder was X rayed again utilizing the remaining contrast medium In all cases the manipulation was performed to the full extent The elevation was detached with the arm in external rotation Internal rotation and extension were



Fig 1
Arthrographically normal axillary fold

forced with some caution considering the possibility of damage to the rotator cuff

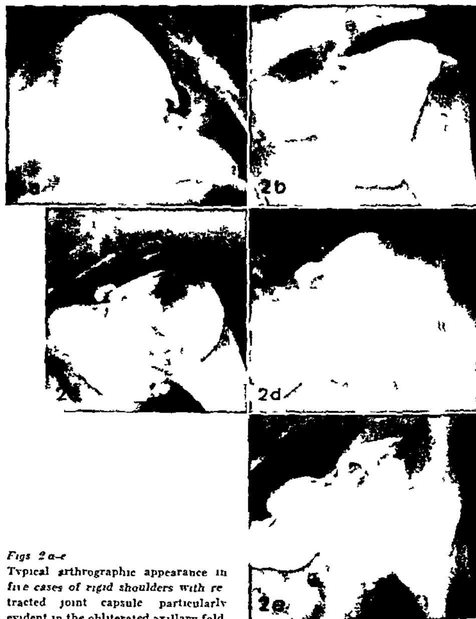
By this technique the appearance of the joint could be studied in connection with 63 manipulative procedures

Prior to the manipulation 45 shoulders showing varying rigidity of different aetiology were visualized by arthrography In 33 cases the underlying cause was humeroscapular periarthritis in 6 cases rupture of the rotator cuff while 6 shoulders were rigid following healing of fractures close to the shoulder joint or surgical procedures on the joint The majority showed a limitation of movement which only permitted an elevation to less than 120° others a somewhat greater elevation but never beyond 150°

After the manipulative procedure 59 arthrographic check up films could be assessed In 45 the diagnosis was humeroscapular periarthritis in 7 rupture of the rotator cuff while in 7 there were other anatomical changes

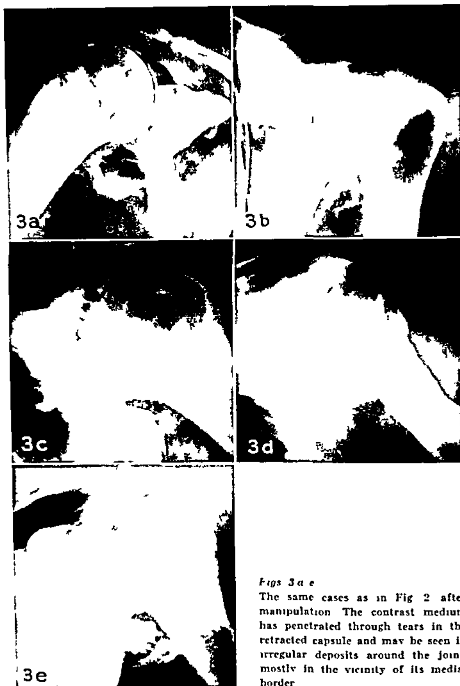
RESULTS AND DISCUSSION

Regardless of the pathogenesis the pre manipulation arthrographies were characterized by obliteration of the articular recesses most marked in the medial axillary fold (Figs 2 a–e) Corresponding to the degree of capsular retraction the joint took a smaller amount of contrast medium (cf *de Sèze* (1961)) In only 4 cases all due to humeroscapular periarthritis was there an inclination to classify the joint capsule as

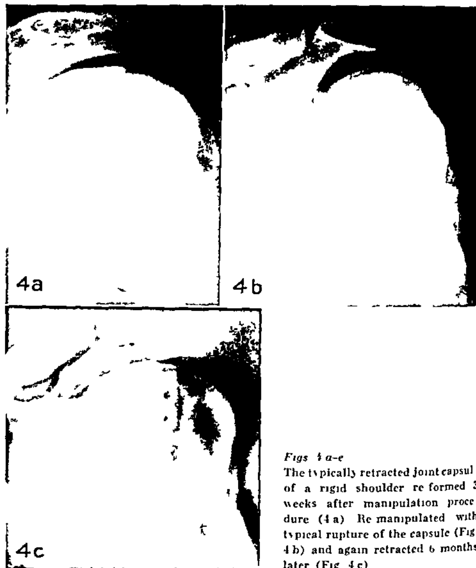


Figs 2 a–e
Typical arthrographic appearance in five cases of rigid shoulders with retracted joint capsule particularly evident in the obliterated axillary fold

normal nevertheless rupture of the capsule as described below occurred during the manipulation in 3 of these 4 cases In the remaining case the limitation of movement was due to pronounced pain inhibition All 6 cases with rupture of the rotator cuff showed capsular obliteration in keeping with *Lidström* s (1963) observations thus representing one



Figs 3 a e
The same cases as in Fig 2 after manipulation The contrast medium has penetrated through tears in the retracted capsule and may be seen in irregular deposits around the joint mostly in the vicinity of its medial border



Figs 4 a–c
The typically retracted joint capsul of a rigid shoulder re formed 3 weeks after manipulation proce dure (4 a) Re manipulated with typical rupture of the capsule (Fig 4 b) and again retracted 6 months later (Fig 4 c)

cause of frozen shoulder In all the pre manipulative arthrograms the joint spaces presented themselves as uninterrupted contrast shadows militating against the occurrence of adhesions between the joint surfaces

The arthrographic check up after the manipulative procedure also showed typical appearances Now the greater part of the contrast medium was outside the joint mainly on its medial side on a level with the neck of the humerus but also beneath the coracoid process



Figs 5 a–c
The contrast medium has accumulated around the joint in a typical fashion after manipulation of rigid shoulder (Fig 5 a) *Six weeks later the mobility is* still limited apparently by a constriction in a re or ganized pouch resembling the axillary fold (Fig 5 b) Full function was restored by re manipulation (Fig 5 c)





and laterally The films showed more or less distinctly the leakage of contrast medium which had occurred through ruptures in the changed joint capsule and which could be correlated to the typical sounds heard during the manipulation (Figs 3 a–c) It was only in one of the 4 above mentioned cases that no leakage could be traced

In 2 instances the manipulation was performed after operative exposure of the shoulder from the anterior aspect Thereby the inter

pretation of the arthrographic films could be confirmed In both in stances a capsular tear was palpable at the site of the medial axillary fold Through this slit the naked joint surface and the shaft of the humerus could be palpated This is in exact confirmity with the de scription given by *Neviaser* (1945) after the dissection of 10 frozen shoulders exposed to forced abduction The capsules were separated the two cut edges retracted leaving a gap of about 2 centimetres

Judging by the arthrographic check ups no damage was done to the tendon apparatus All 36 cases with intact rotator cuff on the pre mani pulative arthrographies who were also arthrographed after the mani pulation, again showed intact tendon apparatus

Even where the rigidity was a consequence of juxtaarticular fractures or arthrotomy there was arthrographically a characteristic obliteration of the joint capsule before the procedure as well as a typical capsular rupture after the manipulation However the limitation of movements was usually of a different quality The resistance to the manipulation is tough and more definitive presumably a sign of co existing contracture or fibrosis of periarticular structures

The appearance of the joint capsule at various times after the mani pulation could also be studied in connection with re manipulation of shoulder joints which still remained rigid In 6 out of 11 cases a cap sular leakage was demonstrable on arthrographies 10 days to 6 weeks after a manipulative procedure In the remaining 5 it had healed 10 days to 6 months later and the capsules were again more or less re tracted (Figs 4 a–c 5 b)

SUMMARY

A series of rigid shoulders was studied arthrographically before and after manipulation under general anaesthesia An almost constant finding on the pre manipulative arthrograms was obliteration of the articular recesses The changes of the joint capsule were similar re gardless of the underlying cause On the basis of these findings shrinkage or retraction of the joint capsule most marked in the medial axillary fold seems to constitute an anatomical bases if any of the limitation of movement in rigid shoulders

An equeally constant finding on the post manipulative arthrograms and also independent of the aetiology was rupture of the changed joint capsule The distribution of the contrast medium indicates that during a manipulative procedure the retracted joint capsule ruptures arthro graphically visualized mainly at the site where the retraction is as a

rule most marked, i.e. in the medial axillary fold. When the capsular retraction also comprises the subcapsular recess the rupture may also include this structure and other parts of a changed joint capsule making up a presupposition of increased mobility.

The material gave no evidence of damage to the rotator cuff during the manipulation.

In cases where mobility is not attained by the manipulation the ruptured joint capsule may resume its retracted shape.

RÉSUMÉ

Une série d'épaules raides ont été étudiées arthrographiquement tant avant qu'après la mobilisation sous narcose.

Une des trouvailles pratiquement constantes a été une oblitération du recessus de la capsule articulaire. Les modifications de la capsule articulaire ont été similaires quel que soit le diagnostic. La rupture de la capsule articulaire modifiéee enregistrée sur les arthrogrammes après la mobilisation est tout aussi constante et indépendante de l'étiologie. On n'a aucune preuve que la mobilisation ait provoqué une lésion de l'aponévrose. La capsule articulaire rompue peut dans les cas où la mobilité n'a pas été obtenue après la manipulation reprendre sa forme rétractive.

ZUSAMMENFASSUNG

Eine Reihe von steifen Schultern wurden sowohl vor als auch nach der Mobilisierung in Narkose mittels Arthrographie untersucht.

Ein nahezu konstanter Befund was dabei eine Obliteration der Gelenksrezesse in den vor der Mobilisierung aufgenommenen Arthrogrammen. Die Gelenskapselveränderungen waren die gleichen unabhängig von der Diagnose. Ebenso konstant und unabhängig von der Ethieologie wurde eine Ruptur der veränderten Gelenkskapsel im Arthrogram nach der Mobilisierung beobachtet. Haltepunkte dass es bei der Mobilisierung zu einer Schädigung der Aponeurose kommt sind niemals vorhanden gewesen.

Die rupturierte Gelenkskapsel kann in den Fällen in denen Beweglichkeit nach der Mobilisierung nicht erreicht wurde ihre retrahierte Form wiedereinnehmen.

pretation of the arthrographic films could be confirmed In both instances a capsular tear was palpable at the site of the medial axillary fold Through this slit the naked joint surface and the shaft of the humerus could be palpated This is in exact confirmity with the description given by *Neviaser* (1945) after the dissection of 10 frozen shoulders exposed to forced abduction The capsules were separated the two cut edges retracted leaving a gap of about 2 centimetres

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Even where the rigidity was a consequence of juxtaarticular fractures or arthrotomy there was arthrographically a characteristic obliteration of the joint capsule before the procedure as well as a typical capsular rupture after the manipulation However the limitation of movements was usually of a different quality The resistance to the manipulation is tough and more definitive presumably a sign of co existing contracture or fibrosis of periarticular structures

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TREATMENT OF RIGID SHOULDERS BY JOINT DISTENSION DURING ARTHROGRAPHY

By

LARS ANDRÉN and BO J. LUNDBERG

Treatment of rigid shoulders aims at curtailing the condition. Since the syndrome is known to disappear spontaneously (*Dickson & Crosby* 1932, *Codman* 1934, *Meulengracht & Schwartz* 1952) it may be difficult to judge the relative value of different therapeutic methods. Complete recovery from the disease is said to be a matter of about one year, rarely more than two. However, of *Simmonds*'s (1949) 21 cases of "frozen shoulder" only 6 recovered full range of motion within 3 years. Judging from these figures, treatment to shorten the duration of disability seems urgent.

In most cases of painful shoulder mobility is restricted. Thus, of *Olsson*'s (1953) series of 77 painful shoulders, 70 per cent were rigid. The stiffness of the shoulder is due to adhesive (*Neviaser* 1945) or retractile (*de Sèze* 1961) capsulitis. During arthrographic examination one of us found reduction in the size of the capsule to be an almost invariable phenomenon in stiff shoulders irrespective of the underlying conditions. The arthrographically obliterated capsule always ruptured on manipulation under anesthesia (*Lundberg* 1965). This finding is incompatible with the opinion of *Bloch* (1958), who reported convincing therapeutic results of manipulation on the basis of 2 000 cases of periarthritis humeroscapularis. He said that "brisement" is not associated with rupture of the obliterated capsule. But arthrography was not done during the manipulation.

Once established rigidity seems not to respond to physiotherapy. Radical manipulation may then be the only way to overcome rigidity promptly (*Storck* 1940). An alternative, less radical, method would however sometimes be desirable.

In connection with arthrography in the routine examination of stiff

ness of the shoulders to assess the degree of capsular retraction and to check the conditions of the rotator cuff one of us (*Andren*) introduced distension of the joint during arthrography This procedure has proved to be of diagnostic as well as therapeutic value also in the treatment of other joints with restricted mobility The technique and some illustrative results are described below

METHOD

The needle is inserted into the joint space lateral to the coracoid process and a local anesthetic is injected The needle is connected via a tube with the syringe Contrast medium (20 ml Urografin® 30 per cent) is then slowly injected until resistance is offered The fluid is then allowed to flow back into the syringe This procedure is repeated several times The patient is instructed to move his arm carefully between the injections If distension requires a larger amount of fluid normal saline is added During such treatment the range of movement of the shoulder gradually increases The procedure is continued until the capsule ruptures as a rule in the wall of the subscapular bursa Sometimes rupture occurs early but then the result is usually less favourable During the injection the typical shoulder pain often radiating down the arm or to the neck is frequently reproduced and disappears on return of the fluid into the syringe

RESULTS

The material consisted of 64 rigid shoulders Of these 11 had a rupture of the rotator cuff and in 15 the rigidity had occurred after fracture of the shoulder joint The remainder were genuine frozen shoulders Treatment was followed immediately by increased mobility in all except 2 Of the 26 patients in whom the stiffness was moderate (total elevation exceeding 120) two thirds immediately recovered full mobility of the joint Of those with more pronounced rigidity 38 cases one fifth recovered full mobility while improvement in the remainder was only partial This group included the 2 above mentioned cases in which the joint could not be distended because of immediate rupture of the capsule

At re examination 2 months after distension the favourable effect of treatment was found to have persisted in the two thirds of the shoulders with a primarily moderate loss of mobility The results achieved in the primarily most rigid group were less favourable One fifth of the patients made a complete recovery On the remainder half improved In the rest the initial improvement wore off In many of this last group repeated treatment produced favourable results while others were treated by manipulation



Fig 3 a–c
An absolutely stiff frozen shoulder in which the joint could n t l e distended Eff ct of injecti n diminished by leakage into the bicipital sheath and to some extent into the axillary recess

ven in successfully treated cases but then later wever not always followed by permanent improve raps is mainly symptomatic the further course is n the activity of the disease Repeated later intra inder pressure may however gradually restore

somet despite unchanged rigidity



Fig. 2 a–c.
Moderate narrowing of articular space in a late healing phase of rigid shoulder (a). Fully distended (b, c) with free mobility.

The method appears most useful in the treatment of slight or moderate rigidity. The distending effect is good in this group, probably owing to greater elasticity and more uniform strength of the shrunken capsule (Fig. 2). Without these properties of the capsule the result is less favourable, especially when rigidity is absolute. For then the pressure of the fluid is not always able to distend the severely retracted capsule because of early rupture (Fig. 3). Such rupture with leakage

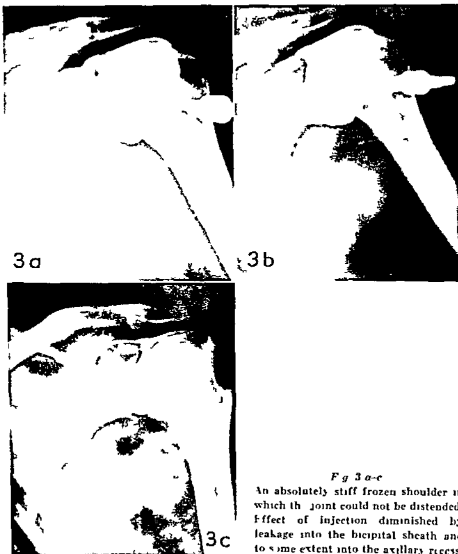


Fig. 3 a–c
An absolutely stiff frozen shoulder in which the joint could not be distended. Effect of injection diminished by leakage into the bicipital sheath and to some extent into the axillary recess.

is liable to occur even in successfully treated cases but then later. Prompt relief is, however, not always followed by permanent improvement. Since this therapy is mainly symptomatic the further course is probably dependent on the activity of the disease. Repeated later intra-articular injections under pressure may, however, gradually restore free mobility (Fig. 4).

Relief from pain is sometimes attained despite unchanged rigidity



Fig 4 a–d

First attempt to distend a highly frozen shoulder (a b) followed 14 days later by more successful distension (c–d) Function restored

Distension of the joint may have the same effect on the condition as manipulation

No complications occurred The pressure exerted in the joint can cause moderate pain radiating from the region of the shoulder and is

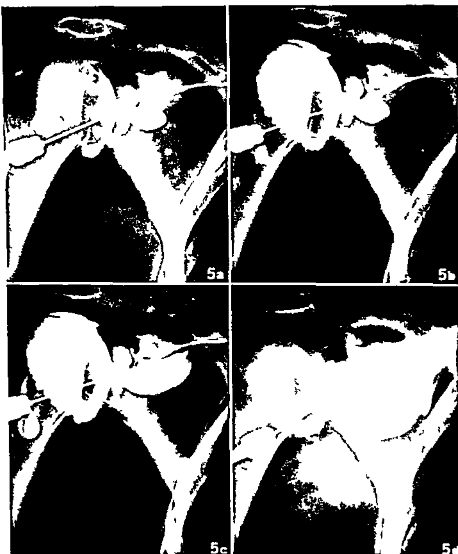


Fig 5 a–d

A frozen shoulder immobile and with very narrowed joint space (a) which is well distended under pressure (b–c) until contrast medium escapes through the sub capsular recess (d) Immediatel afterwards full function

recognized as typical by the patient The radiating pain in a rigid shoulder originates from the affected joint and is not due to cervical rhizopathy

The immediate improvement creates great expectations for the



Fig 4 a–d
First attempt to distend a highly frozen shoulder (a–b) followed 14 days later by more successful distension (c–d) Function restored

Distension of the joint may have the same effect on the condition as manipulation

No complications occurred The pressure exerted in the joint can cause moderate pain radiating from the region of the shoulder and is

nounced Even though the outcome is less predictable in such severe cases one or more attempts are recommended (Fig 5)

Fractures affecting the shoulder joint diminish its range of motion mainly by dislocation callus formation or organized periarticular tissue However in our material capsular obliteration was invariably present then as in cases of rigidity of other origin As in genuine frozen shoulders it is thus possible to increase mobility by distension (Fig 6)

SUMMARY

In rigid shoulders intraarticular injection under pressure with consequent distension of the joint capsule will often result in partial or complete recovery of mobility of the joint

RESUME

Dans les epaules rigides une injection intraarticulaire sous pression provoquant une distension de la capsule articulaire a souvent comme resultat un retablissement partiel ou complet de la mobilite de l'articulation

ZUSAMMENFASSUNG

Bei Schulterversteifung wird die intraartikulare Injektion unter Druck mit folgender Ausdehnung der Gelenkskapsel oft eine teilweise oder vollständige Wiederherstellung der Beweglichkeit des Gelenkes ergeben

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EXPERIENCE OF ARTHROPLASTY OF THE ELBOW

By

LARS UNANDER SCHARIN and STEN KARLHOLM

Limitation of movement and pain in one or both elbow joints is an extremely disabling condition involving difficulty in working eating and in managing one s personal simple duties etc Very naturally therefore surgical procedures have been devised in the attempt to improve these conditions which mainly attend rheumatoid arthritis and fractures of the elbow joints

The common features of the arthroplasty procedures described by *Payr* (1934) *Putti* (1921) *McAusland* (1921), *Albee* (1931) and *Ryerson* (1944) are that by resection an attempt is made to make the new joint resemble the old one to create good stability and mobility and to relieve pain The methods differ mainly in the choice of the interposed material and in the way of making the incisions

In contrast *Julius Hass* (1944) has suggested a method involving a more radical transformation of the joint surfaces This method creates a new joint in which the contact between the bony ends is reduced as far as at all possible

TECHNIQUE

A U shaped posterior incision with the convexity downward extending from epicondyle to epicondyle (Fig 1) The ulnar nerve is freed and held aside The olecranon is chiselled off and carried proximad with the triceps tendon Thereafter the ulna and radius are formed into a *wide trough in which the posterior margin of the ulna* stands up a bit higher From the trochlea and capitulum humeri a transverse wedge is formed by the chisel Both surfaces of this wedge reach to the olecranon fossa and the coronoid fossa An effort is made to preserve the collateral ligaments If a synostosis is present between the radius and ulna it is

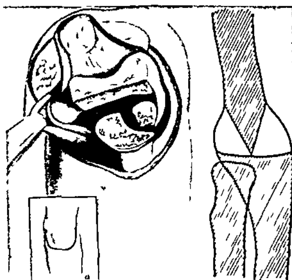
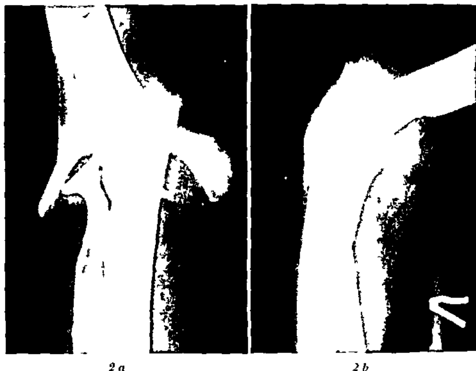


Fig 1
From Julius Hass (1944)

divided and the ulnar aspect of the radius is chiselled into wedge shape The head of the radius may be resected entirely or partially *Hass* does not feel that an interposed material is needed but if it is used he recommends a fat graft from *e g* the thigh Some surgeons recommend fascia lata or skin We have used fat The graft is fastened to the pointed end of the humerus either by transosseous sutures or to the fibrous joint capsule which unlike the synovial joint capsule should not be included in the resection Possibly the most important function of the graft is to fill the dead spaces in the anterior and posterior joint and thus prevent the formation of haematoma

That part of the olecranon which is attached to the triceps tendon is extirpated wholly or partially Thereafter the triceps tendon is fixed to the ulna by strong catgut sutures through burr holes The ulnar nerve is transposed to the anterior joint The skin is sutured Previously we immobilized the arm in extension but have now changed our practice to immobilizing it is 90 flexion for two weeks At the end of this period active exercises of flexion and extension are instituted

Frequently there is a tendency to instability in the elbow joint In that event the patients are provided with an elbow bandage for some time It would seem wise to prescribe an elbow bandage in all cases showing a tendency to annoying instability It is of the utmost importance to



Figs 2–4
Radiograms about two years after operation.
The patients suffered from rheumatoid arthritis.

enjoin upon the patient an intensive training of the arm muscles. This training should be started even before the operation; in complete ankylosis this means of course only contraction of the muscles.

In the further course the joint undergoes a functional adaptation, the distal transverse trough on the ulna deepening and the straight transverse end of the humerus getting rounded and smoothened in the centre so that it acquires a fork-like shape (Figs 2–4). At times an olecranon-like projection develops on the ulna.

MATERIAL

Nineteen patients have been treated by the named method. Fifteen were suffering from rheumatoid arthritis and 4 from post-traumatic osteoarthritis. Their age distribution and sex ratio are shown in Table 1. Out of the rheumatoid cases 11 had ankylosis or almost complete ankylosis, while 4 had fairly good but painful mobility in the joint. All the post-traumatic cases had considerable limitation of movement. The excursion before and after the operation is recorded in Tables 2 and 3. In one



3 a



3 b



4 a





4 b

case no improvement of movement was obtained This patient was in an extremely poor general condition and had weak muscles All the others obtained a fairly good or good mobility Two patients both of whom had primarily had satisfactory but very painful movements complained of pain or approximately the same type after the operation In three cases there was considerable instability These patients were later provided with an articulated elbow brace with which they were completely satisfied The muscular strength in the elbow joints has been tested and found to be approximately corresponding to the patients strength in other joints

TABLE 1
Age and Sex Distribution in the Present Series

	Men	Women
10–20	–	3
21–30	1	3
31–40	3	1
41–50	–	1
51–60	2	3
61–70	–	2
	6	13

TABLE 2
Extension Flexion Mobility before and after Arthroplasty in Cases of Rheumatoid Arthritis

Before operation	Follow up in months	After operation
160	5	140–90
90	4	100–90
90	144	140–25
135	144	180–65
100	108	150–105
90	6	145–95
110–90	4	180–40
140–75	48	120–80
100–90	144	165–50
160–40	12	170–30
180–90	6	180–60
90	6	140–40
90	3	140–80
140–80	12	170–40
90	12	170–60

TABLE 3

Extension Flexion Mobility before and after Arthroplasty in Traumatic Cases

Before operation	Follow up in months	After operation
150	24	180–80
120–90	20	180–90
100–90	6	180–60
100–90	6	140–60

The patients working ability has varied and they have not been enabled to perform heavy work. In cases the symptoms from other joints were so severe that the patients were unable to do any work but their social situation was appreciably improved by the operation The remaining 14 patients are capable of working

DISCUSSION

Hass has reported on 15 cases with a follow up period ranging from 3 to 12 years Out of this series 8 were classified as excellent 3 as good 1 as fair and 3 as poor All three failures had a history of osteomyelitis and the ankylosis persisted despite the operation None of our cases was post infectious and we have also not had any infections in connection with the operation According to *Hass* the best results are obtained by operations on ankylotic elbow joints

During the period 1921–1948 a total of 93 arthroplasties were performed in the Campbell Clinic Of the 45 patients who were followed 56 per cent had obtained good 22 per cent fair and 2 per cent poor results while 20 per cent were considered failures In a report on this material *Knight & van Saint* (1952) point out that the greatest proportion of good results was found among the patients in whom ankylosis followed closed fracture or fracture dislocation but they also state that in 50 per cent of the patients in whom ankylosis followed open fracture or fracture dislocation arthroplasty was a failure With antibiotic therapy this high incidence of failure should be greatly diminished As far as we can see patients with a good but painful mobility in the elbow joint do not appear to be suited for this type of arthroplasty as also pointed out by *Vainio* (1962) and *Harvey* (1963)

Harvey (1963) has reported 15 cases 10 of whom had been followed up for one year or longer All these patients had rheumatoid arthritis *Harvey* emphasizes that in general young patients obtain better results than older patients and he goes on the state that "a fibrous or bony ankylosis is best for operation with least likely recurrence of the disease

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CONCLUSION

Previous and present experience appears to indicate that elbow joints with greatly limited mobility or complete ankylosis in patients with rheumatoid arthritis or post traumatic conditions are best suited for arthroplasty Post infectious conditions of the elbow joint do not appear to be suited for arthroplasty as this involves a risk of a flare up of the infectious process Another type of case which does not appear to be suited is that of a good but painful mobility

SUMMARY

Nineteen patients with greatly limited mobility or severely painful *movements in the elbow joint were submitted to arthroplasty The* results assessed at follow up from 3 to 144 months after the operation were found to be good in 15 cases

RESUME

19 cas avec mobilite considerablement reduite ou douleurs prononcees au mouvement dans l articulation du coude ont ete l objet d une arthroplastie Le resultat de l intervention a éte etudie entre 3 et 144 mois apres l operation et a ete juge bon dans 15 cas

ZUSAMMENFASSUNG

19 Falle von bedeutend eingeschränkter Beweglichkeit oder ausgesprochenen Bewegungsschmerzen im Ellbogengelenk waren der Gegenstand einer Arthroplastik Das Ergebnis wurde von 3 bis 144 Monaten nach der Operation studiert und wurde in 15 Fallen als gut angesehen

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PREDICTION OF AVASCULAR NECROSIS FOLLOWING CERVICAL FRACTURE OF THE FEMUR BASED ON CLEARANCE OF RADIOACTIVE IODINE FROM THE HEAD OF THE FEMUR

By

B Holmquist and P A Alffram

INTRODUCTION

Approximately one third of femoral neck fractures result in avascular necrosis of the head of the femur (*Hulth & Johansson* 1962) and about two thirds of the patients with such necrosis suffer considerable invalidity (*Jensenius* 1956) Until to day efforts to reduce the incidence of avascular manifestations after femoral neck fractures have been relatively unproductive However modern techniques for replacing a destroyed femoral head with a vitallium prosthesis supplemented by a reliable method for determining the viability of the femoral head at the time of fracture would be useful in avoiding repeated surgical interventions due to avascular necrosis in these often already debilitated patients

In 1934 *Phemister* stated that the fate of the femoral head in cases of femoral neck fractures is dependent on the damage to the blood supply and is determined at the time of fracture During the last two decades assessment of the viability of the femoral head in such cases has been attempted by such methods as venography (*Hulth* 1953 1956 *Dahlgren* 1959 *Hulth & Johansson* 1962) arteriography (*Rook* 1953 *Mussbichler* 1956) radioactive tracer techniques (*Tucker* 1950 *Boyd* 1951 *Arden & Veall* 1953 *Boyd Zilversmit & Calandruccio* 19?? *Laing*

Financial support was obtained from the *Josiah Macy Jr Foundation* and from the *Knut and Alice Wallenberg Foundation* Stockholm

& *Ferguson* 1959 *Arden* 1960 *Johansson* 1962 *Boyd & Calandruccio* 1963) needle aspiration (*Harrison* 1962) dye clearance technique (*Price* 1962) and oximetry (*Woodhouse* 1961) Few of these studies compare the long term results with the initial assessment of the blood circulation to the femoral head In the present study the results of an initial radioactive tracer clearance technique have been related to radiographic follow up two and one half years or more after fracture

MATERIAL

Thirty two unselected patients with recent cervical fracture of the femur were studied Thirty fractures were nailed immediately after the assessment Two fractures studied at 7 and 84 days respectively after fracture were considered impacted and stable and therefore were not nailed The age of the patients varied from 43 to 86 years Roentgenographic follow up was possible in 25 cases 22 patients were examined three years or more after fracture and two patients were followed two and one half years One patient suffered an extensive avascular necrosis of the femoral head during the first year after fracture and was subjected to a Moore arthroplasty Six patients were dead at the time of follow up and one patient refused examination

METHOD

The type of fracture was classified with respect to the displacement of the fracture fragments on initial roentgenograms and the fracture-shaft angle (FSA) on frontal view (*Hulth* 1956) usually assessed on roentgenograms taken during operation It was also noted whether or not there was a valgus position after nailing

At the time of nailing of the fracture intraosseous injection of ^{131}I in sterile isotonic saline was performed by means of a specially designed cannula[1] with a volume of 0 05 ml and a glass syringe containing 0 15 ml of solution (Fig 1) The cannula was inserted into the femoral head through a lateral approach after reposition of the fracture had been made and the position of the cannula was checked roentgenographically (Fig 2) 0 10 ml of the solution corresponding to 10 micro-

1 The authors wish to express their gratitude to *C. M Berger* managing director and *C Dahl* chief engineer AB Malkus Holmquist Halmstad for the construction of the cannula used in these studies

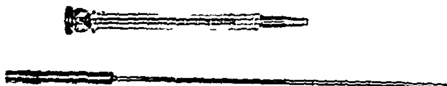


Fig 1
Syringe and cannula used in the investigation



Fig 2
Roentgenogram showing cannula in position during examination

curie ^{131}I was injected and the cannula was immediately washed out by injection of 0 05 ml isotonic saline At specific time intervals after the injection the activity over the hip was measured by the equipment described by *Bauer & Wendeberg* (1959) A 12 wide-angle collimator was used throughout the investigation with the aperture of the collimator close to the skin during the measurements The activity data were

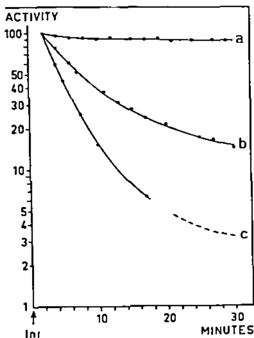


Fig 3

Typical disappearance curve.
a cervical fracture which resulted in avascular necrosis
b cervical fracture which later healed without signs of avascularity
c traumatic dislocation of the hip

corrected for background activity which was determined at every measurement. The rate of disappearance of radioactive iodine could then be determined (Fig 3). The pressure increase within the femoral head due to the injected solutions was arbitrarily assumed to have disappeared after 5 minutes. Therefore the decline in measured radioactivity from 5 to 15 minutes after injection expressed as per cent of the 5 minutes value was used as an indicator of the blood circulation to the femoral head.

RESULTS

The roentgenographic results at follow up with other relevant data are given in Table 1. All measurements but one were made in fresh fractures.

All fractures healed without signs of pseudarthrosis. Roentgenographic evidence of avascular necrosis of the femoral head was pre

sent in 9 cases In 2 of these the avascular changes were restricted to the cranial portion of the head while in the others the changes were diffuse

TABLE 1

Case	Sex	Age	Primary displacement	Valgus after nailing	F S A	Interval between fracture and assessment (days)	Interval between assessment and follow up (mth)	Disappearance (per cent)	Necrosis of head
1	♀	74	++	—	>30	11	12	0 5	total
2	♀	53	—	+	>30	6	48	3 6	total
3	♂	60	+	—	>30	6	52	2 4	total
4	♀	63	+	—	<30	2	40	3 4	total
5	♀	64	+	—	>30	6	61	4 0	total
6	♀	74	++	—	<30	4	40	3 5	total
7	♀	52	—	+	>30	7	52	11 6	partial Not nailed
8	♀	43	++	+	<30	6	51	3 0	partial
9	♂	78	++	—	<30	6	56	4 1	partial
10	♂	61	—	+	>30	6	62	39 0	none
11	♀	55	—	—	<30	8	62	19 1	none
12	♂	57	++	—	<30	4	62	2 2	none
13	♀	48	+	+	>30	4	40	2 1	none
14	♂	55	+	—	>30	6	60	5 3	none
15	♀	56	++	+	<30	1	55	6 3	none
16	♂	74	+	—	<30	7	51	46 6	none
17	♀	79	++	—	>30	4	30	24 2	none
18	♀	76	++	—	<30	4	59	6 7	none
19	♂	66	+	—	<30	4	54	5 6	none
20	♀	83	—	+	>30	84	58	42 7	Malum coxae Not nailed
21	♂	56	+	—	>30	4	55	9 6	none
22	♀	55	—	—	>30	5	36	49 0	none
23	♀	64	+	—	>30	6	55	14 5	none
24	♀	78	++	—	>30	4	58	28 5	none
25	♀	74	+	—	>30	7	30	4 5	none

The decline in radioactivity between 5 and 15 minutes after injection was less than 5 per cent in 8 of the cases that subsequently underwent avascular necrosis In one case with partial necrosis of the head the disappearance rate was 11 6 per cent This fracture was impacted in valgus and was not nailed

Of the 16 cases without signs of avascularity at follow up the clearance was above 5 per cent in 13 and below 5 per cent in 3 cases One of

the latter fractures was nailed in valgus and the initial displacement was moderate Another case with a disappearance rate of 4 5 per cent was followed for only 30 months after fracture

Since 1 of 14 fractures with a disappearance rate above 5 per cent and 8 of 11 fractures with a disappearance rate below 5 per cent resulted in avascular necrosis the reliability of this method is 84 per cent

The degree of primary displacement the fracture shaft angle or the valgus position after nailing could not be demonstrated to influence the occurrence of avascular necrosis in this small series

DISCUSSION

To day there are several methods by which the viability of the femoral head can be assessed after a femoral neck fracture with about the same reliability By measuring the oxygen tension in the femoral head *Woodhouse* (1961) found a positive correlation in 17 of 19 cases In evaluable venographies (*Hulth & Johansson* 1962) a correct prediction of the viability could be made in about 80 per cent and similar reliability was obtained by the different radioactive tests described by *Arden* (1960) *Boyd & Calandruccio* (1963) and *Johansson* (1964) In these methods however one quarter to one third of the tests were not evaluable By measuring the transport of isotoptagged red cells to the femoral head *Vassiu* (1964) predicted total avascularity with almost complete accuracy In the present series where no tests were omitted a correct prediction of the viability of the femoral head was made in 84 per cent of the cases

A disappearance rate of less than 5 per cent during 10 minutes strongly indicates avascularity of the femoral head whereas avascular necrosis was rare above that level This is in agreement with the findings of *Laing & Ferguson Jr* (1959) who in animal experiments found total avascularity in cases with a clearance below 5 per cent 10 minutes after injection and normal blood supply in cases with a clearance above 20 per cent Between these values the femoral head was partially devascularised

Injection of large volumes may damage the bone tissue of the femoral head (*Hulth* 1956) and cause increased intraosseous pressure forcing the tracer solution along the cannula into the fracture space resulting in incorrect assessments Therefore the total volume injected in this method was reduced to a minimum by the specially designed cannula

with a volume of 0.05 ml. The pressure effects of such a small volume injected in this method is certainly negligible.

The position of the tip of the cannula in the femoral head is probably also essential. In case 8 where the cannula was inserted centrally in the head and injection made into probably vascularized bone, there were signs of partial avascular necrosis despite the high disappearance rate of 11.6 per cent. The accuracy of the method can probably be increased by inserting the cannula into the proximal part of the femoral head where partial necrosis is most commonly seen.

The method prolongs the operating time by about 15 minutes. It seems, however, possible to reduce this delay by at least 5 minutes by measuring the disappearance rate during the first 10 minutes from the time of injection.

SUMMARY

In 32 unselected patients with recent cervical fracture of the femur the vascularity of the femoral head was assessed by means of a radio-active tracer clearance technique. 25 patients were followed roentgenographically not less than 30 months. In 21 of these 25 cases the prognosis regarding survival of the femoral head could be correctly predicted.

RESUME

Chez 32 malades non selectionnes ayant presente une fracture cervicale recente du femur, la vascularisation dans la tete femorale a ete controlee au moyen de la technique du traceur radio-actif. 25 malades ont ete suivis radiographiquement pendant environ 30 mois. Chez 21 de ces 25 cas, le pronostic par rapport a la survie de la tete femorale a pu etre correctement etabli.

ZUSAMMENFASSUNG

Bei 32 nicht ausgewählten Patienten mit frischen Schenkelhalsbrüchen wurde die Blutversorgung des Femurkopfes mittels einer radioaktiven Aufspurungstechnik bestimmt. 25 Patienten wurden nicht weniger als während 30 Monaten nachuntersucht. Bei 21 von diesen 25 Fällen konnte die Prognose hinsichtlich des Überlebens des Oberschenkelkopfes richtig vorausgesagt werden.

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LATE RESULTS OF PERTHES' DISEASE

By

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This paper is concerned with an investigation of the late clinical and radiological results of Perthes disease

MATERIAL

The material consisted of 40 patients with Perthes disease The diagnosis was radiologically verified in all cases Two patients had in the meantime emigrated 2 had died and one could not be traced The remaining 35 patients (28 men and 7 women) were after examined clinically and radiologically (Table 1) The interval between the onset of the disease and the present after-examination was at least 20 years on the average 33 years (32 for men and 37 for women)

The disease was right sided in 22 cases and left sided in 13 The average age at onset was 7.4 years (7.7 in the men and 6.0 in the women) The lowest age at onset was 3 years the highest 13 years

All patients except 2 had been treated with bed rest The average duration was 6.1 months In 23 cases (19 men and 4 women) the hip was immobilised in plaster for an average period of 3.2 months Except in 2 cases treatment included freedom from weight bearing (plaster bed rest crutches) for on the average 6.6 months

METHODS

The patients were after examined clinically and radiologically in 1964 Thirteen of the patients had also been examined radiologically in 1949 1955 The clinical examination included evaluation of pain range of motion and restriction of function (*Danielsson* 1964) Radiological evaluation[1] was performed on frontal lateral and Lauenstein views The degree of arthrosis was assessed according to Heripret's schema (*Danielsson et al* 1964) The series was divided into 4 groups according to degree of deformity of the femoral head Lowest degrees of deformity in the different groups 1 2 and 3 are illustrated in Figs 1 2 and 3 The length of the caput collum was measured after which the ratios between the values of the hip joint without and with Perthes disease were calculated

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The investigation was supported by grants from *Ulla and Gustaf af Ugglas Foundation* Stockholm

1 Radiographs interpreted in cooperation with Dr *B Frost*

TABLE I

Total Material.

Case	Sex	Age [illegible]	Interval between [illegible] and [illegible] after [illegible] (years)	[illegible]	[illegible]	[illegible]	[illegible]	Severity [illegible]	[illegible]	[illegible]	[illegible]	Degree [illegible]
1	F	06	31	14	00	14	×	0 0	70 82	02	[illegible] [illegible]	2
2	F	04	42	06	06	06	×	0 0	21 43	06	2221 2110	2
3	M	12	42	07	07	07		0 0	33 70	01	2223 1101	2
4	F	11	42	06	02	06	×	0 0	92 47	01	[illegible] 2121	2
5	M	11	43	02	01	02		0 1	74 57	02	[illegible] 1021	2
6	M	04	35	03	03	03		0 0	94 94	03	[illegible] [illegible]	0
7	M	05	35	02	02	02	×	0 0	92 92	00	[illegible] [illegible]	1
8	M	12	22	07	00	12		0 0	53 82	01	1110 [illegible]	2
9	F	05	[illegible]	06	06	06		0 0	96 81	01	[illegible] [illegible]	2
10	M	03	46	09	09	09		2 0	53 73	02	2121 1000	3
11	F	07	[illegible]	00	01	00	✓	0 0	92 84	02	0000 0000	1
12	F	02	44	06	[illegible]	06	✓	0 0	83 94	01	0000 0000	1
13	M	05	[illegible]	04	04	04	✓	0 0	92 82	01	0000 0000	[illegible]
14	M	10	44	04	02	04		2 0	53 79	03	[illegible] [illegible]	
15	M	03	37	04	07	04		0 0	92 92	01	[illegible] [illegible]	
16	M	03	25	11	11	1		0 0	90 90	01	[illegible]	
17	M	05	23	09	09	09	✓	0 0	37 86	1		

P[illegible] [illegible]ed subluxation.

TABLE 1 (cont.)

Case	Sex	Age at onset of pain	Interval between onset and examination (years)	Bed rest (months)	From [illegible] plaster (months)	Free from weight bearing (months)	Complete freedom from pain after [illegible] stage	Severity of pain	Range of motion	Restriction of function	Radiological [illegible]	Degree of [illegible]
18	M	11	45	10	07	10	×	0 0	70 75	02	1010 0000	3
19	M	04	22	01	00	01	×	0 0	86 86	03	0000 0000	0
20	M	08	29	05	03	05		0 2	85 24	03	0000 0010	3
21	M	07	31	03	03	06	×	0 0	70 85	02	0000 0000	2
22	M	07	35	03	01	04	×	0 0	66 71	01	1010 0000	2
23	M	07	20	02	00	03	×	0 0	81 81	01	0000 0000	0
24	M	10	20	12	00	18	×	0 0	76 83	01	1000 0000	2
25	M	07	22	08	08	08	×	0 0	92 92	01	0000 1010	1
26	M	10	22	15	00	15		0 0	65 85	01	2010 0000	2
27	M	09	26	00	00	00	×	0 0	68 82	01	0000 0000	3
28	M	06	23	17	00	[illegible]	×	0 0	91 91	01	0000 0000	0
29	M	10	22	08	00	08		0 0	82 86	01	2010 0000	[illegible]
30	M	05	56	06	06	07		5 0	36 74	12	1 11 0000	3
31	M	09	29	04	04	04	×	0 0	78 65	02	0000 1000	3
32	F	07	29	06	06	06	×	0 0	84 90	01	0000 0000	1
33	M	11	36	03	03	03		0 2	80 62	04	0000 3231	3
34	M	07	36	05	04	0		1 0	29 82	04	[illegible] 1000	3
35	M	04	41	04	03	04	×	0 0	87 88	02	0000 0010	0

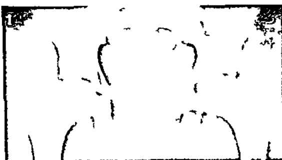


Fig 1
(Case 16) Male aged 33 Right sided Perthes disease at 8 years Hip painless Range of motion normal (90) No restriction of function (01) Deformity of the head classified as 1 No arthrosis



Fig 2
(Case 24) Male aged 31 Right sided Perthes disease at 10 years Hip painless Range of motion excellent (76) No restriction of function (01) Deformity of the head classified as 2 No arthrosis

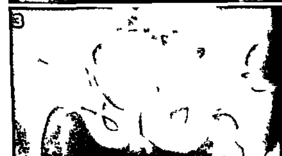


Fig 3
(Case 03) Male aged 54 Right sided Perthes disease at 12 years Hip painless Range of motion good (38) No restriction of function (01) Deformity of the head classified as 3 Arthrosis (07)

RESULTS

Pain

Pain at onset had been localised to the following sites greater trochanter in 13 groin in 5 and knee joint in 3 The corresponding figures at the after examination were 7 3 and 2

Two patients reported starting pain 2 spontaneous pain during rest 2 pain after exercise (disappeared during rest) one severe pain when walking and 5 slight pain when walking Fourteen patients (all men) reported that they had on one or more occasions had hip pain At after examination 7 patients (all men) complained of pain (Fig 4) while 28 (21 men and 7 women) were free from pain

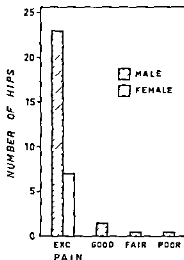


Fig 4
Number of hips classified according to severity of pain and patient's sex

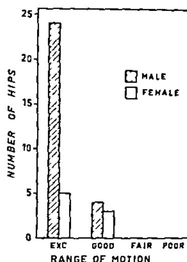


Fig 5
Number of hips classified according to range of motion and patient's sex

Range of Motion

Nine patients (all men) had normal range of motion of the hip. All patients had excellent or good range of motion (Fig 5). The mean index of range of motion for the hips with Perthes disease was 69 ± 3.2 and for the contralateral side 83 ± 0.8.

Contracture

Contractures were noted in all together 6 patients (4 men and 2 women). *Contracture in flexion* 1–15° was noted in one man and one women, 16–30° in 2 men and one woman. Two men had *contracture in adduction* 1–15°. *Contracture in external rotation* 1–15° was recorded in one woman, 16–30° in one man and one woman, and 31–45° in one man.

Restriction of Function

All except 3 (men) could walk more than 1500 meters without hip pain. Of these one complained of pain after 400–1500 meters and 2 after 100–400 meters. One man and one woman could not tie up their shoe laces. One man had to use the handrail when walking upstairs, all the others could walk upstairs without support. No patients reported any difficulties with the use of the toilet. One man could not take a

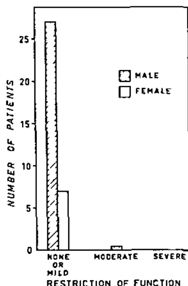


Fig 6

Number of patients classified according to restriction of function and sex

bath and one woman found it difficult One man had a positive Trendelenburg test One man had a severe limp while 5 men and 2 women had a slight limp Restriction of function was inconsiderable (Fig 6) and the index was on the average 2 1 ± 0 34 (Restriction of function None or Mild for values 0–6)

Shortness of the leg (≥ 1 cm anterior superior iliac spine—medial malleolus) was noted in 15 patients (13 men and 2 women) Atrophy of the thigh (≥ 1 cm) was recorded in 22 patients (19 men and 3 women)

Radiological Changes

The degree of deformity was judged as severe in 13 cases as moderate in 8 as slight in 8 and in 6 no deformity of the femoral head was noted (Fig 7)

Arthrotic changes (structural changes and/or narrowing of the joint space) were demonstrated in 17 hips (15 men and 2 women) Of these structural changes alone were seen in 10 and in combination with narrowing of the joint space in 7 In 8 the joint space seemed to be wider on the affected side (Fig 2)

Of the 13 patients examined radiologically 1949–1955 the arthrotic changes had progressed in 6 while in 7 the roentgen appearance was largely the same in 1964



Fig 7
(Case 28) Male aged 29 Right sided Perthes disease at 6 years (a) 1935 (b) No deformity of the head No arthrosis 1964 (c) No pain Range of motion normal (91) No restriction of function (01) No deformity of the head No arthrosis

Comparisons

Age at onset of Perthes disease appeared to influence the clinical and radiological picture at the after examination It is clear from Table 2 that pain decreased range of motion and restriction of function as well as arthrotic changes and deformity of the femoral head tended to be more common and more severe among those in whom the onset was late than early

The interval between the onset of the disease and the after examination also influenced the clinical and radiological picture Table 3 shows that pain decreased range of motion restriction of function and arthrotic changes tended to be more common among those with a long interval since onset of the disease

TABLE 2

Cases Classified According to Age at Onset of Perthes Disease and Severity of Pain Range of Motion Restriction of Function Radiological Severity and Deformity of the Head

Age at onset	Pain		Range of motion		Restriction of function		Radiological severity		Deformity	
	0	≥1	≥70	<70	<4	≥4	<3	≥3	<2	≥2
<8	17	2	15	4	18	1	16	3	12	7
≥8	11	5	5	11	13	3	8	8	2	14

TABLE 3

Cases Classified According to the Interval Since Onset of Perthes Disease and Severity of Pain Range of Motion Restriction of Function and Radiological Severity

Interval (years)	Pain		Range of motion		Restriction of function		Radiological severity	
	0	≥1	≥0	<0	<4	≥4	<3	≥3
<30	13	1	9	5	14	0	12	2
≥30	15	6	11	10	1[illegible]	4	12	9

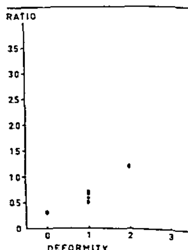


Fig 1

Deformity classified according to head neck length ratio

TABLE 4

Cases Classified According to the Deformity of the Head and Severity of Pain Range of Motion Restriction of Function and Radiological Severity

Deformity	Pain		Range of motion		Restriction of function		Radiological severity	
	0	≥1	≥ 0	< 0	≤4	>4	<3	3
<2	14	0	14	0	14	0	14	0
≥2	14	7	6	15	17	4	10	11

TABLE 5

Cases Classified According to Radiological Severity and Severity of Pain Range of Motion and Restriction of Function

Radiological severity	Pain		Range of motion		Restriction of function	
	0	>1	≥ 0	0	≤4	>4
<3	26	2	20	8	27	4
≥8	2	5	0	7	1	3

TABLE 6

Comparison between Patients with Perthes Disease and Primary Coxarthrosis Classified According to Age Severity of Pain Restriction of Function and Radiological Severity

	Age	Severity of pain	Restriction of function	Radiological severity
Perthes disease	0 5 ± 0 01	69 ± 3 2	2 1 ± 0 34	2 1 ± 0 46
Primary coxarthrosis (*Danielsson* 1964)	2 3 ± 0 07	36 ± 2 4	10 0 ± 0 61	6 4 ± 0 13

A correlation was found between the head neck length ratio and the deformity of the femoral head (Fig 8)

Deformity of the femoral head also had an unfavourable effect on the clinical and radiological picture (Table 4) Pain decreased range of motion restriction of function and arthrotic changes tended to be more common among those with severe than among those with slight deformity of the femoral head

The severity of arthrosis influenced the clinical picture Table 5 shows that the number of patients with pain decreased range of motion and restriction of function tended to be larger in the group with the

most severe arthrotic changes It was also found that of the 10 patients with structural changes alone only 2 had pain and an average range of motion of 68 ± 4 6 while of those 7 patients with both structural changes and narrowed joint space all except 2 had pain and an average index of range of motion of 46 ± 4 7

Pain tended to vary with *contracture* Of the 6 patients with contracture 4 had or had had hip pain

In this series no correlation was found between *the type of treatment given* and the clinical or radiological status at the time of the after examination nor between *overweight* and pain

DISCUSSION

Sundt (1949) found at after examination of 137 cases with a history of more than 10 years that the results were better in patients in whom the disease had appeared early in life *Ratliff* (1956) and *Mose* (1964) arrived at the same conclusion on the basis of series of 50 and 219 patients respectively The results noted in the present investigation corroborate those reported by *Sundt Ratliff* and *Mose*

Sundt (1949) found the roentgen appearance of the hip to be normal in 11 of 153 cases with Perthes disease for more than 10 years and *Helbo* (1953) in 4 of 41 patients for more than 25 years The corresponding figures in the present material was 6 of 35

Sundt (1949) found in his material arthrosis in 47 of 96 cases with a history of more than 20 years In the present investigation structural changes and or narrowing of the joint space were noted in 17 of 35 cases

The clinical and radiological pictures were good and better than those found in a series of primary coxarthrosis (*Danielsson* 1964) It is difficult to judge to what extent this may be ascribable to the higher age of the patients in the latter series (Table 6)

As to the correlation between age at onset of Perthes disease interval between onset and after examination and clinical and radiological picture the series is too small to allow any definite conclusions However arthrosis tended to be more advanced and more common among those with a late onset with a longe interval or with a high degree of deformity

SUMMARY

35 patients with Perthes disease were after examined clinically and radiologically on the average 33 years after the onset of the disease

TABLE 4

Cases Classified According to the Deformity of the Head and Severity of Pain Range of Motion Restriction of Function and Radiological Severity

Deformity	Pain		Range of motion		Restriction of function		Radiological severity	
	0	≥1	0	< 0	<4	≥4	<3	≥3
<2	14	0	14	0	14	0	14	0
≥2	14	7	6	15	17	4	10	11

TABLE 5

Cases Classified According to Radiological Severity and Severity of Pain Range of Motion and Restriction of Function

Radiological severity	Pain		Range of motion		Restriction of function	
	0	≥1	> 0	< 0	<4	≥4
<3	26	2	20	8	27	4
≥8	2	5	0	7	1	3

TABLE 6

Comparison between Patients with Perthes Disease and Primary Coxarthrosis Classified According to Age Severity of Pain Restriction of Function and Radiological Severity

	Age	Severity of pain	Restriction of function	Radiological severity
Perthes disease	0 5 ± 0 01	69 ± 3 2	2 1 ± 0 34	2 1 ± 0 46
Primary coxarthrosis (*Danielsson* 1964)	2 3 ± 0 07	36 ± 2 4	10 0 ± 0 61	6 4 ± 0 13

A correlation was found between the head neck length ratio and the deformity of the femoral head (Fig 8)

Deformity of the femoral head also had an unfavourable effect on the clinical and radiological picture (Table 4) Pain decreased range of motion restriction of function and arthrotic changes tended to be more common among those with severe than among those with slight deformity of the femoral head

The severity of arthrosis influenced the clinical picture Table 5 shows that the number of patients with pain decreased range of motion and restriction of function tended to be larger in the group with the

periode fortgeschritten Hohes Alter beim Beginn langer Zeitraum zwischen Beginn und Nachuntersuchung und schwere Verbildung schienen die Arthrose zu begünstigen

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THE VOSS OPERATION IN OSTEOARTHRITIS OF THE HIP

By

GOSTA KOLLBERG and GUNNAR LUNDHOLM

INTRODUCTION

Osteoarthritis of the hip is generally speaking a disease of advanced age so that owing to increased longevity it is acquiring ever greater importance However the condition is not restricted to the elderly but may be encountered in far younger age groups It must be expected that in the future we shall have ever more to do with this disease

The pathological changes in osteoarthritis of the hip consist briefly in degeneration of the cartilage which loses its elasticity This gives rise to subchondral sclerosis formation of cysts and osteophytes in the joint margins All these changes are visualized by X rays

Among the aetiological factors incongruence in the joint is probably the most important one This incongruence may be due to several causes It may be congenital due to dysplasia of the femoral head or acetabulum or both with or without co existing subluxation of the joint It may be acquired for instance a sequel of coxa plana or epiphysiolysis and it may of course also be traumatic Another aetiological factor is no doubt joint infection Yet another group is made up by so-called senile osteoarthritis whose cause has not yet been definitely elucidated

The three symptoms which predominate in osteoarthritis of the hip are pain limitation of movement and an incorrect position

In general the pain is the most disturbing symptom and the one which makes the patient consult a doctor A distinction is made between pain on exertion and pain at rest

The limitation of movement is partially explicable by the deforming changes but is no doubt often pain conditioned

Pronounced contractures of the muscles and other soft tissues gives rise to incorrect positions mainly a position of flexion and adduction

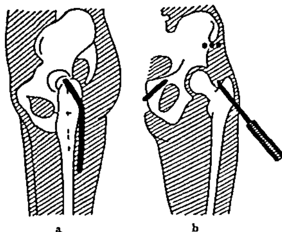


Fig 1
The Voss operation
a) Lateral incision of the skin (———) and the incision of the fascia (-----)
b) Operative field from the anterior aspect The skin incision (——— and -----) and the site of cutting the bone and muscles

The treatment of ostearthritis of the hip is varied Conservative methods have their value but as a rule their effect is merely transient In the more disabling cases considervative treatment is usually of little use The disease has therefore been treated by various surgical procedures of which only arthrodesis arthroplasties and intertrochanteric osteotomies will be mentioned here The last mentioned type of operation seems to have been predominant during the past few decades

SURGICAL METHOD

In 1955 Voss described a new surgical procedure for the treatment of osteoarthritis of the hip the so-called temporary hanging hip ("temporare Hengehufte") which is based on an entirely new principle In his opinion the most important factor is that the muscles around the joint are in a state of increased tension Owing to this increased muscular tension the articular cartilage is exposed to an abnormal pressure causing a so-called pressure osteoarthritis Accordingly the therapeutic principle should be an attempt to interrupt this condition of abnormal muscle tension Thereby the pressure in the joint is decreased and the cartilage is afforded a possibility for regeneration

Normally the pressure in the hip joint is due mainly to the muscles surrounding the joint According to *Pauwel's* (1961) calculations this so-called dynamic muscle pressure is about four times the pressure caused by the weight of the body upon weight bearing *e g* walking Muscular contractures in osteoarthritis of the hip may

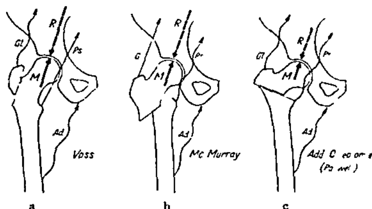


Fig 2

The effect of surgery by the method of Voss MacMurray and Pauwel is obtained by decreasing the tension of the muscles around the hip joint

multiply this pressure In other words the joint is exposed to considerable force *Voss* method involves (Fig 1)

(1) Tenotomy of the fascia lata by a cross incision
(2) Chiselling of the greater trochanter or tenotomy of the attachments of the gluteus medius and gluteus minimus on the greater trochanter
(3) Adductor tenotomy
(4) Tenotomy of the anterior iliac spine muscles

Simultaneously with the adductor tenotomy it is easy to excise the obturator nerve This modification was used in about half our cases

The effects of Voss operation MacMurray s osteotomy and Pauwels osteotomy are illustrated in Fig 2

AFTER TREATMENT

In Voss method the after treatment is of the utmost importance as pointed out by many authors not least by *Voss* himself On the whole we have followed the instructions given by *Voss* After the operation the patient performs activating exercises from the very first day while he is kept in bed with a hip traction of 3 kg Anticoagulant therapy was instituted on the third day After three weeks in bed during which the patient is often allowed to sit he is taken into a walking chair and as soon as possible he is permitted to walk with two Canadian crutches without supporting on the operated leg The stay in hospital is a total of 5-6 weeks On discharge the patients are instructed not to subject the leg to weight bearing to any extent for another 6 weeks

MATERIAL

From the autumn of 1961 through 196 42 patients were submitted to the Voss operation in the Karlstad Clinic Two cases were bilateral so that the material comprises 44 hips Twenty four of the patients were females and 18 males (Table 1) The average age was 61 years range 46–71 years (Table 2) The material consists of patients with osteoarthritis of the hip of varying aetiology cases with evident joint incongruence predominating X ra s showed in most cases severe osteoarthritis and in some cases moderate osteoarthritis No ca e had mild radiological changes.

TABLE 1
Osteoarthritis of the Hip Treat d by the Voss Operation

18 ♂
24 ♀ 42 patients (44 operations)

Right hip	1?
Left hip	23
Bilateral	2
Voss operation only	24
Voss operation + excision of obturator nerve	20

TABLE 2
Age Distribution of the 42 Patients who Underwent Voss Operation

	♂	♀
40–49	–	2
50–59	4	9
60–69	13	13
70–79	1	–

The indications for Voss operation was long lasting s mptoms which did not respond to any maj r extent to conservative treatment The majority of the operated patients had previou ly spent some time in hospital to have conservati e treatment The radiologic l changes played no notable part in deciding the indications.

RESULTS AND DISCUSSION

The follow up period is short but not shorter than 6 months (Table 3) In our series however the results in the three groups having different follow up periods were similar

We investigated pain on weight bearing pain at rest the distance which the patients could walk and the mobility of the hip (Table 4) Before the operation all the patients had pain on weight bearing and 40 also had pain at rest After the operation a distinct improvement of the pain on weight bearing had been obtained in 39 out of the 44 cases Four were unchanged and one worse The pain at rest improved in 36 cases remained unchanged in 3 and aggravated in one case

TABLE 3
Follow Up Period
(44 operations)

6–12 months	15
12–18 months	14
18–24 months	15

TABLE 4
Result of Voss Operation
(In some cases supplemented by excision of the obturator nerve)

	Pain on weightbearing	Pain at rest	Walking distance	Mobility of hip
Improved	39	36	28	15
Unchanged	4	3	13	26
Worse	1	1	3	3

TABLE 5
Final Assessment

	Subjective	Objective
Improved	36 (82 %)	35 (80 %)
Unchanged	6	7
Worse	2	2

The walking distance had increased in 28 cases considerably in some e g from 20–30 m to a couple of km

The mobility of the hip had increased in 15 cases but as a rule there was no major increase In several cases there was an improvement of the incorrect position of the hip joint Thus like *Harff & Wandschneider* (1962) we were unable to find any essential increase in hip mobility unlike *Seyfarth* (1948) and *Voss* (1956) who recorded such an increase Some degree of muscular insufficiency is common after the operation but it is transient and as a rule not annoying to the patient

In about half our cases the Voss operation was supplemented by excision of the obturator nerve The results in these cases were the same as following the Voss operation alone

In the final evaluation the main emphasis was laid on the patients statements regarding the pain Our final assessment was based on the patients subjective interpretation and the objective findings (Table 5)

The results are in keeping with those of others For instance *Kunlscher* (1962) reported 82 per cent good results in a series of approx 500 cases *Weickert* (1961) obtained 89 per cent good results among 39 cases and a number of others have reported 70–80 per cent good results

Among operative complications infection was of most importance in our series as it occurred in not less than 4 cases (9 per cent) which is a high incidence The infecting organism was *Staph aureus* in all cases Three subsided without any *lasting sequel while one patient* developed severe coxitis and remained in hospital for more than 6 months the end result was poor

Bilateral thrombosis is the lower legs despite prophylactic anticoagulant therapy was recorded in one case In this connection it may be mentioned that in a series of 41 patients *Harff & Wandschneider* (1962) had two fatal cases of embolism *Voigt* (1958) too has reported death from embolism Thus although the Voss operation is a relatively minor procedure it is not quite devoid of risk

SUMMARY

The Voss operation *i e* so called temporary hanging hip (temporare Hengehufte) *has proved an applicable method in the treatment* of osteoarthritis of the hip In 42 patients (two with bilateral involvement) it resulted in considerable improvement in about 80 per cent The improvement consisted in appreciably decreased pain on weight bearing and at rest and to some extent an increased walking distance and increased mobility of the hip Besides the method possesses the advantage of being a relatively minor procedure

RESUME

Une operation d apres la methode de Voss dans ce qu on appelle la hanche pendante temporaire s est montree etre une methode utilisable dans le *traitement de la coxarthrose L opération a provoque chez* 42 malades (deux malades operes bilatéralement) une amelioration marquée dans environ 80 pour cent des cas une diminution marquee des douleurs en position de charge et de repos et dans une certaine mesure une plus grande liberte de marche et une mobilite accrue de la hanche Parmi les avantages de la methode on peut mentionner qu il s agit *d une intervention relativement* peu importante

ZUSAMMENFASSUNG

Die Operation nach Voss zur Erreichung einer zeitweiligen Hängehüfte hat sich als anwendbare Methode zur Behandlung der Coxarthrose erwiesen Die Operation gab bei 42 Patienten (zwei Patienten wurden doppelseitig operiert) eine deutliche Besserung in ungefähr 80 Prozent mit erheblich verringerten Belastungs und Ruheschmerzen und bis zu einem gewissen Grade verlängerter Gangstrecke samt gesteigerter Hüftbeweglichkeit Zu den Vorteilen der Methode gehört dass sie ein verhältnismässig geringer Eingriff ist

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THE EFFECT OF CRUSH INJURY TO THE SKIN ON HEALING OF FRACTURE OF THE SHAFT OF THE TIBIA IN DOGS

By

PER EDWARDS

INTRODUCTION

In a clinical investigation of fractures of the shaft of the tibia (*Bauer, Edwards & Widmark* 1962) it was found that the incidence of infection delayed union and poor end results was directly related to the etiology of the fractures the results were uniformly good in fractures caused by moderate indirect violence and were relatively poor in fractures caused by severe direct violence These results were interpreted to suggest that the prognosis in fractures of the shaft of the tibia was related more to the severity of soft tissue damage than to the bone injury

This hypothesis was tested in a prospective series of the shaft of the tibia in man special attention was given to the management of the skin injury In comparison with an earlier control series of fractures this policy resulted in a lower incidence of necrosis of the skin and osteomyelitis associated with improved final status of the fractures (*Edwards* 1965)

The results of the clinical investigation were confirmed by the findings in a series of experimental fractures of the tibia in dogs reported here

MATERIAL AND METHODS

Both tibia were fractured in each of 15 mongrel dogs weighing about 20 kg The fractures were produced by a blow first to one and then the

Financial support was obtained from *Herman Järnhardt's Stiftelse* Malmö and *Fylgias 80-års fond* Stockholm

ZUSAMMENFASSUNG

Die Operation nach Voss zur Erreichung einer zeitweiligen Hengehüfte hat sich als anwendbare Methode zur Behandlung der Coxarthrose erwiesen Die Operation gab bei 42 Patienten (zwei Patienten wurden doppelseitig operiert) eine deutliche Besserung in ungefähr 80 Prozent mit erheblich verringerten Belastungs und Ruheschmerzen und bis zu einem gewissen Grade verlängerter Gangstrecke samtgesteigerter Huftbeweglichkeit Zu den Vorteilen der Methode gehört dass sie ein verhältnismässig geringer Eingriff ist

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Fig 2

Dog no 11 showing a typical fracture comminuted and moderately displaced

After fracture new plaster bandages were applied under anaesthesia to both the control and experimental extremities at intervals of 2 weeks or less The incidence of necrosis of the skin and of osteomyelitis and the time of clinical healing of the fractures were recorded

RESULTS

A *Complications*

In 12 of the 15 dogs necrosis of the skin and or osteomyelitis occurred (Fig 3) These complications were found only on the experimental extremity and never on the control extremity

Three dogs all with deep necrosis of the skin (exposure of bone) died 3 weeks after fracture Two of these died during anaesthesia for the re application of plaster and one for unknown reasons

B *Healing Time*

In the 12 dogs that survived until both fractures of the tibia had healed the healing time was shorter on the control than on the experi

mental side (Table 1) The healing time on the control side did not differ much between animals 4 weeks or less in 10 animals and all 12 control fractures healed within 6 weeks

The experimental side fractures were still un united in 3 dogs which were sacrificed 13 14 and 22 weeks after fracture The healing times in the other 9 experimental fractures ranged from 6 to 16 weeks with a mean of about 9 weeks

TABLE 1

Incidence of Complications and Time for Clinical Union in Fractures of the Shaft of the Tibia in Dogs

Dog	Body Wt (kg)	Fracture force (kgf)	Complications		Healing time (weeks)	
			Necrosis of the skin	Osteomyelitis	Control	Experimental
1	27	11	+	—	4	>22
2	16	10	++	—	4	8
3	24	14	—	—	4	14
4	18	14	+	—	4	6
5	14	14	+	—	4	>14
6	18	23	—	—	6	8
7	23	23	—	—	4	8
8	18	23	++	—	6	12
9	19	23	+	—	4	6
10	18	23	+	—	4	8
11	13	23	++	—	4	9
12	23	23	++	++	3	>13
13	19	11	++	?	—	
14	25	14	++	?	6	×
15	20	23	++	?	6	

× Dog died 3 weeks after fracture

DISCUSSION

Infection of fractures of the tibia in man is a complication which may cause non union or at best prolongation of the healing time (*Watson Jones & Coltart* 1943 *Nicoll* 1964 *Edwards* 1965) The latter author has emphasized the association of skin necrosis with osteomyelitis

In the surviving dogs reported here 9 of the 12 fractures on the experimental side were associated with necrosis of the skin In 4 of those the necrosis was so deep that the fracture was exposed However only one of these developed osteomyelitis with fistula formation This observation confirms the fact that the dog is less susceptible to infection of bone than is man It was observed that skin defects were rapidly



Fig 3



Fig 4

Fig 3 Dog no 11 Deep necrosis of the skin with exposure of the fracture

Fig 4 Dog no 11 3 weeks later The skin defect is covered with granulation tissue

covered with granulation tissue (Fig 3 and 4) An alternative possibility would be that the dogs harbored an infection in the slow healing fractures of such low grade or atypical type that criteria for the diagnosis osteomyelitis were not met

The association between a crushing blow to the lower leg necrosis of the skin and delayed or non union of fracture of the shaft of the tibia was firmly established in the experiment reported here In the absence of signs of severe infection it is not possible to explain the cause of this association

SUMMARY

Bilateral fractures of the shaft of the tibia were produced in 15 dogs on one side with and on the other side without production of crush injury to the skin The initial skin injury developed into necrosis of the skin in 12 dogs and into osteomyelitis in one In all 12 dogs surviving the initial phase of the experiment the time for healing of the fractures was markedly prolonged in 9 and probably significantly prolonged in all These data are interpreted as evidence of a causal relationship between skin injury and poor healing of fractures of the shaft of the tibia as observed in man

RESUME

Des fractures bilatérales du corps du tibia ont été provoquées chez 15 chiens d'un côté avec lésion de la peau au choc de l'autre côté sans lésion. Il s'est développé une nécrose de l'épiderme blessé chez les 12 chiens et une ostéomyélite chez un. Chez tous les 12 chiens qui ont survécu à la phase initiale de l'expérience la durée de guérison des fractures a été beaucoup plus prolongée chez 9 et probablement nettement prolongée chez tous. Ces données sont interprétées comme la preuve d'une relation causale entre la lésion de l'épiderme et la mauvaise guérison des fractures du corps du tibia observée chez l'homme.

ZUSAMMENFASSUNG

Doppelseitige Brüche des Schaftes der Tibia wurden bei 15 Hunden auf einer Seite mit und auf der anderen Seite ohne Quetschungsschäden der Haut erzeugt. Die ursprüngliche Hautbeschädigung entwickelte sich zu einer Hautnekrose bei 12 Hunden und zu einer Osteomyelitis bei einem. Bei allen 12 Hunden, die die Anfangsphase des Experimentes überlebten, war die Heilungszeit der Brüche ausgesprochen verlängert bei 9 und wahrscheinlich bedeutend verlängert bei allen. Diese Daten werden als ein Beweis des ursächlichen Zusammenhanges zwischen Hautbeschädigung und schlechter Heilungstendenz von Schaftbrüchen der Tibia, wie sie am Menschen zu beobachten ist, angesehen.

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FRACTURE OF THE SHAFT OF THE TIBIA

Incidence of Complications as a Function of Age and Sex

By

GORAN C H BAUER and PER EDWARDS

INTRODUCTION

In a consecutive series of 173 fractures of the shaft of the tibia *Bauer, Edwards & Widmark* (1962) showed that the occurrence of poor results was frequent in fractures caused by direct high energy forces and infrequent in fractures caused by indirect low energy forces It was suggested that this difference in final status of the cases was related to the degree of skin injury seen in the two groups of fractures those caused by direct forces had suffered crush injury of the skin obvious in open fractures but probably present also in closed fractures In a series of experimental fractures of the tibia in dogs (*Edwards* 1965a) it was found that the rate of healing was delayed in those fractures which had a crush injury of the skin over the fracture It seemed possible that poor results in fracture of the shaft of the tibia could be prevented by paying close attention to the associated skin injury *Edwards* (1965b) accordingly modified the treatment of such fractures In a Prospective Series of 109 transverse or comminuted displaced fractures of the shaft of the tibia 47 of which were open only one had a poor final status whereas in a Control Series 21 of [illegible] transverse or comminuted displaced fractures had poor final status The one case in the Prospective Series which had a poor final status had necrosis of the skin and osteomyelitis there was a high incidence and close correlation between these complications in the 21 fractures in the Control Series which had poor final status The importance of necrosis of the skin and subsequent osteomyelitis as a factor in the etiology of poor results of fracture of the shaft of the tibia was thus esta-

Edwards also confirmed the correlation between crush injury of the skin and subsequent necrosis of the skin this complication did not occur in the 149 longitudinal displaced fractures in the combined series in spite of a high frequency of open reduction and internal fixation (76 per cent) which in the Control Series was always performed through an incision over the antero medial surface of the tibia In the closed transverse or comminuted fractures necrosis of the skin was observed only in those treated by open reduction through an incision over the fracture

In an attempt to further analyze the cause of necrosis of the skin osteomyelitis and poor final status in fracture of the shaft of the tibia the effect of age and sex on these variables was studied in the transverse fractures of *Edwards* (1965b) Control Series

MATERIAL AND METHODS

A *Definitions*

In accordance with *Edwards* (1965b) the following definitions were used

Transverse fractures all fractures in which the fracture line formed an angle of 45 to 90 degrees with the long axis of the shaft and all comminuted fractures i e those with one or more intermediate fragments involving at least half of the bone diameter By definition double fractures were thus included in this group

Longitudinal fractures all other fractures i e fractures which have been classed long spiral fractures or long oblique fractures

Superficial necrosis of the skin necrosis of the skin located over the antero medial surface of the tibia *and* over the fracture region with no exposure of bone

Deep necrosis of the skin necrosis of the skin located over the antero medial surface of the tibia *and* over the fracture region with exposure of bone

Mild osteomyelitis obvious infection with fistula formation where the time required for healing and cessation of drainage was less than one year

Severe osteomyelitis obvious infection with fistula formation where the time required for healing and cessation of drainage was more than one year

Good Final Status essentially complete recovery of normal function

Fair Final Status minor limitation of function and/or subjective complaints

Poor Final Status Amputation pseudarthrosis chronic osteomyelitis or severe limitation of function and subjective complaints

In addition a distinction was made between patients according to age

Young patients patients below age 45

Old patients patients 45 years old or older

B *Selection of Patients*

The patients selected for the analysis reported here belonged to the Control Series of *Edwards* (1965b) As seen in Table 1 only 1 of the 92 fractures with complications and none of 21 fractures classified as poor with regard to final status belonged to fracture types other than displaced transverse either open or closed

Therefore *displaced closed and open transverse fractures* (subsets 4 and 5 of Table 1) *formed the material studied here*. Evaluation of complications (necrosis of the skin and/or osteomyelitis) was made in all 165 transverse fractures, 71 of which were open, and evaluation of final status 2 to 10 years after fracture was made in 151 fractures, 64 of which were open.

Fractures with complications and/or poor final status are listed in Table 4. *Edwards* (1965b) contains full information on these and all other fractures analyzed here.

TABLE 1

Anatomic Classification of Fractures of the Shaft of the Tibia

Anatomic classification	Subset number	Number of fractures		
		Total	With complication	Poor final status
Displaced longitudinal closed	1	118	1	–
Displaced longitudinal open	2	7	–	–
Undisplaced longitudinal open	3	–	–	–
Displaced transverse closed	4	94	7	7
Displaced transverse open	5	71	21	14
Undisplaced transverse open	6	4	–	–
Undisplaced transverse closed	7	17	–	–
Undisplaced longitudinal closed	8	–	–	–
Total		311	29	21

TABLE 2

Incidence of Primary Complications in Displaced Transverse Fractures of the Shaft of the Tibia as a Function of Age in Males

Fracture type	Number of fractures			
	Below age 45		Above age 45	
	Total	Complicated	Total	Complicated
Closed reduced openly	27	2	16	5
Closed reduced closed	18	0	10	0
Open wound smaller than 6 cm	27	3	16	6
Open wound larger than 6 cm	5	2	12	9
Total	77	7	54	20

RESULTS

A. *Incidence of Complications*

1. *Males (Table 2 and Fig. 1)*. Twenty-seven out of 131 transverse fractures developed necrosis of the skin and/or osteomyelitis. None of

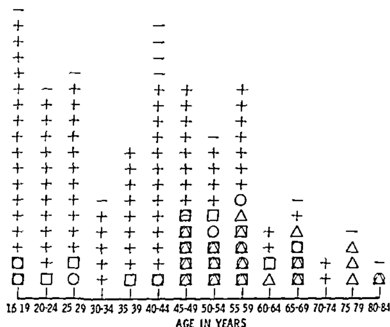


Fig 1

Complications and final status in transverse fracture of the shaft of the Tibia in Males

- □ Necrosis
- ○ Osteomyelitis
- △ Poor final rating
- — Not rated
- + Rated absence of complications

TABLE 3

Final Status of Displaced Transverse Fractures of the Shaft of the Tibia as a Function of Age in Males

Age groups	Final status				
	Good	Fair	Poor	Unrated	Total
16–29	32	10	–	3	45
30–44	19	9	–	5	33
45 59	15	6	12	2	35
60 90	4	3	8	3	18
Total	70	28	20	13	131

these complications developed in the 28 closed fractures which were not openly reduced The incidence of complications in open transverse fractures and closed transverse fractures openly reduced was significantly higher above age 45 (20/44) than below age 45 (7/59) A combination of deep necrosis of the skin *and* severe osteomyelitis occurred in 10 fractures above age 45 and in only 1 fracture below age 45

2 *Females* Only 1 out of 34 transverse fractures developed a complication a superficial necrosis of the skin in a 17 year old with an open fracture Sixteen of the females above age 45 had either open fractures or closed fractures treated by open reduction The incidence of complications in this group was thus significantly lower than in the corresponding group in males

B *Incidence of Poor Final Status*

1 *Males* (*Table 3 and Fig 1*) The final status was found to be progressively less satisfactory with advancing age Out of 118 fractures classifiable as regards final status 70 occurred before age 45 and 48 after age 45 All of the 20 fractures classified as poor belonged to the latter group

2 *Females* Only 1 of the 33 fractures classifiable as regards final status was found to be poor

TABLE 4

Transverse Fractures with Complications and/or Poor Final Status

1	2	3	4	5	6	7	8
153	—	+	18	M	+	+	a
163	—	+	26	M	—	++	b
183	—	+	57	M	—	++	c
184	—	+	60	M	—	—	c
186	—	+	65	M	++	++	c
187	—	+	65	M	++	++	c
188	—	+	66	M	++	++	l
190	—	+	76	M	—	—	c
191	—	+	84	M	—	++	c
(220) 218	—	—	79	M	—	—	c
225	++	—	17	F	+	—	b
228	++	—	70	F	—	—	c
33	+	+	19	M	+	+	l
235	++	+	[illegible]	M	+	—	a
236	+	+	28	M	++	—	a
248	++	+	47	M	++	++	c
249	++	+	48	M	++	++	

TABLE 4 (cont.)

1	2	3	4	5	6		8
250	+	+	48	M	++	+	x
251	+	+	51	M	—	+	b
252	++	+	54	M	++	++	c
253	+	+	54	M	++	++	c
254	++	+	54	M	++	++	c
255	++	+	56	M	+	—	c
(259) 257	+	+	58	M	—	++	c
(257) 259	+	+	58	M	—	—	c
274	++	—	38	M	+	—	b
277	+	—	44	M	++	++	a
280	++	—	45	M	+	++	c
282	++	—	47	M	++	++	c
283	++	—	51	M	+	—	a
284	++	—	56	M	++	++	c
286	+	—	53	M	—	++	a
287	+	—	64	M	+	—	b
288	+	—	67	M	—	—	c
(218) 290	+	—	79	M	—	—	c

1 *Code Number in Edwards* (1965b) which contains full information on these and all other fractures analyzed here
2 *Size of wound* — none + less than 6 cm ++ more than 6 cm
3 *Initial Treatment* — closed reduction + open reduction
4 *Age*
5 *Sex*
6 *Necrosis of the Skin* — none + superficial ++ deep
7 *Osteomyelitis* — none + mild ++ severe
8 *Final Status* a good
b fair
c poor
x not classifiable

DISCUSSION

The results of the analysis reported here clearly demonstrate the multifactorial etiology of poor results of treatment of fractures of the shaft of the tibia. All fractures classified as poor with regard to final status were of the transverse type (transverse, short oblique or comminuted), *i.e.* they were usually caused by direct severe violence. However, in this group of fractures with a relatively poor prognosis a distinction could be made on the basis of sex and age. The incidence of poor final status was 1 in 33 females and 20 in 118 males. This

difference was not due to any corresponding difference in severity of the fractures (vide infra)

Among males all fractures with poor final status occurred above age 45 This difference between young and old males was further emphasized by the finding that the incidence and severity of complications was also significantly higher in fractures occurring in males above age 45 *Edwards* (1965b) has shown that in the material discussed here the occurrence of poor final status was correlated with the occurrence of osteomyelitis and that the occurrence of osteomyelitis was correlated with the occurrence of necrosis of the skin The chain of events leading to poor final status thus starts with the skin injury and proceeds through necrosis of the skin to infecion and osteomyelitis *Edwards* (1965b) was able to prevent osteomyelitis and poor final status by paying attention to the skin injury These findings would explain the age and sex dependent difference in final status following transverse fracture of the shaft of the tibia reported here the prognosis was relatively poor in older males because there was less resistance to skin necrosis following crush injury and in some cases superimposed trauma caused by open reduction and internal fixation Unfortunately not enough is known about the individual patients to permit analysis of this factor One may speculate that arteriosclerosis is important

At any rate the relatively poor prognosis in older males was directly related to the nature of the injury and the immediate course of events nothing in this material suggested any relation to age dependent differences in either rate of bone healing or psychological factors such as motivation or imminent retirement

The difference between sexes was particularly evident when a comparison was made in transverse fractures which occurred above age 45 and which were either open or closed openly reduced Sixteen females and 44 males met these criteria Complications developed in 20 of the males and in none of the females

Finally in the entire material 92 per cent of 278 classifiable fractures were rated as good or fair It would seem difficult to improve this value The analysis here however showed that in a specific group of patients constituting only one-sixth of the entire material the prognosis was poor in one third of the fractures By contrast the prognosis was poor in less than 1 per cent of the rest of the material Unfortunately attempts at isolation of subsets with particular characteristics from fracture or other orthopaedic case materials remains difficult because few authors publish all observations made in the course of a clinical

investigation. Isolation of such subsets provides a powerful means for the identification of etiologic factors significant in the prevention and treatment of disease.

SUMMARY

In a consecutive series of 311 traumatic fractures of the shaft of the tibia the final status and the incidence of complications were analyzed as a function of sex and age. It was found that all 20 of the 21 fractures classified as poor with regard to final status occurred in males above age 45 who had an open, or a closed openly reduced, transverse, short oblique or comminuted fracture. In this set of fractures the incidence of necrosis of the skin and/or osteomyelitis was 20/44 in males above age 45, 7/59 in males below 45, and 1/25 in females, sixteen of whom were above age 45.

It is concluded that males above age 45 with fracture of the shaft of the tibia caused by direct severe violence constitute a group in whom the skin is particularly prone to develop necrosis with subsequent osteomyelitis and poor function as a result.

RÉSUMÉ

Dans une série consécutive de 311 fractures traumatiques du corps du tibia, le bilan final et l'incidence des complications ont été analysés en fonction du sexe et de l'âge. Il est apparu que 20 des 21 fractures classées comme ayant donné un résultat piètre en ce qui concerne le bilan final appartenaient à des hommes âgés d'environ 45 ans et qui avaient une fracture ouverte ou une fracture fermée réduite ouvertement, transversale, oblique courte ou comminutive. Dans ce genre de fractures l'incidence de la nécrose de l'épiderme et/ou d'ostéomyélite était 20/44 chez les hommes âgés de plus de 45 ans, 7/59 chez les hommes de moins de 45 ans et 1/25 chez les femmes, dont seize avaient plus de 45 ans.

Il est conclu que les hommes âgés de plus de 45 ans avec fracture du corps du tibia causée par violence directe grave constituent un groupe chez lequel l'épiderme a particulièrement tendance à développer une nécrose avec ostéomyélite subséquente d'où il en résulte une mauvaise fonction.

ZUSAMMENFASSUNG

In einer Reihenfolge von 311 traumatischen Bruchen des Schaftes der Tibia wurden der Endzustand und das Vorkommen von Komplikationen als eine Funktion des Geschlechtes und des Alters analysiert Es wurde gefunden dass 20 von 21 Brüchen die hinsichtlich ihres Endzustandes als schlecht bezeichnet wurden bei Männern über 45 Jahren auftraten die einen offenen oder geschlossenen offen reponierten transversen kurzen Schräg oder Splitterbruch hatten In diesem Frakturmateriale war das Auftreten von Hautnekrose und oder Osteomyelitis folgendermassen verteilt 20/44 bei Männern über 45 Jahren 7/59 bei Männern unter 45 Jahren und 1/2 bei Frauen von denen sechzehn über 45 Jahre alt waren

Man schliesst daraus dass Männer uber 45 Jahren mit einem durch direkte schwere Gewalt erzeugten Bruch des Tibiaschaftes eine Gruppe darstellen in der die Haut besonders zur Entwicklung einer Nekrose mit folgender Osteomyelitis geneigt ist mit dem Ergebnis einer schlechten Funktion

ACKNOWLEDGEMENTS

Financial support was obtained from U.S Public Health Service (Training Grant No T1 AM 5414 and General Support Grant No 1 SO1 FR 05495)

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Acta orthop Scandinav 36 104-111 1965

From the Orthopaedic Research Laboratories (Head Goran C H Bauer M D) of the Orthopaedic Department (Head Sophus von Rosen M D) Malmo General Hospital University of Lund Malmo Sweden and of the Hospital for Special Surgery affiliated with The New York Hospital Cornell University Medical College New York City

GRAPHIC REPRESENTATION OF HEALING TIME IN FRACTURES OF THE SHAFT OF THE TIBIA

By

PER EDWARDS and BO E R NILSSON

INTRODUCTION

The time required for union of a fracture of the shaft of the tibia is one criterion for judging the efficiency of treatment In common with most authors *Ellis* (1958) chose 20 weeks as the upper limit for normal healing time *Delayed union and non union are, however difficult to define with regard to time*

Henderson (1926) stated that delayed or non union was more common in open fractures and *Owen* (1932) pointed out that non union was more frequent in fractures caused by direct violence *Urist et al* (1954) showed that healing time was related to the anatomical type of fracture The purpose of this paper is to evaluate the influence on healing time of various factors such as anatomical type of fracture etiology infection and treatment

MATERIAL

The material consisted of 492 consecutive fractures of the shaft of the tibia in adults treated in the Orthopaedic Department of the University of Lund at the Malmo General Hospital during the years 1949 through 1963 The cases were divided into a control series (311 fractures) in which no standardized treatment was given and a prospective series (181 fractures) where treatment was modified as regards skin injuries to prevent osteomyelitis A *detailed description of these cases* has been published by *Edwards* (1965)

A *Definitions*

Transverse fractures fractures in which the fracture line formed an angle between 45 and 90 degrees with the long axis of the shaft and fractures in which one or more

intermediate fragments involved at least half of the bone diameter (comminuted fractures)

These fractures were generally the result of direct severe violence such as traffic accidents and crush injuries

Longitudinal fractures all other fractures i e spiral and long oblique fractures

These fractures were generally the result of indirect moderate violence such as falls at the ground level or from a height of less than 3 meters

Displaced fractures fractures with longitudinal or transverse displacement regardless of angulation

Open fractures fractures where a wound communicated with the fracture

Osteomyelitis bone infection with fistula formation

METHODS

A Estimation of Healing Time

Healing time was defined as the interval from injury to clinical union of the fracture Stability was evaluated every time the plaster was removed Generally the healing time was equal to the period of plaster fixation This method tends to overestimate the actual time for union In the prospective series more attention was paid to healing time and the overestimate may be less

TABLE 1

Displaced Closed Longitudinal Fractures (Method of Calculation)

Col 1 Month	Col 2 Number	Col 3 Acc no	Col 4 Corr no	Col 5	Col 6 Probit
1	1	164	163.5	99.09	7.36
2	35	129	128.5	77.9	5.77
3	63	66	65.5	39.7	4.74
4	42	24	23.5	14.2	3.93
5	17	7	6.5	3.9	3.24
6	4	3	2.5	1.5	2.83
7	2	1	0.5	0.3	2.25
12	1				
	165				

Column 1 Time in months following fracture

Column 2 Number of fractures observed to be healed at corresponding time

Column 3 The numbers are reversely accumulated to represent the number of fractures not yet healed at corresponding time

Column 4 The accumulated numbers are corrected by —0.5 units according to the method of *Moore et al* (1951)

Column 5 The accumulated corrected numbers are expressed as per cent of the total number of fractures derived from Column 2

Column 6 Probits derived from a probit table are taken for the corresponding percentages

B. *Analysis of Data*

1. *Calculations.* Probit analysis was used to evaluate the healing time for various groups of fractures. The steps in the calculations are found in Table 1 as they were applied to the closed displaced longitudinal fractures.

The probits from Column 6 in Table 1 were plotted against time in months where time was made a logarithmic function. The best line was fitted by eye (Fig. 3). In the line fitting little attention was paid to the points representing the extreme periods as these points were based upon very few fractures. The times required for healing of 50 per cent and 95 per cent of the fractures were derived from the graphs and are listed in Table 2 and 3. These times correspond to probits 5.00 and 3.36 respectively.

TABLE 2

Healing Time for Different Types of Fractures (Control and Prospective Series)

Type of fracture	No.	Months required for healing of 50% of the group	Months required for healing of 95% of the group
Displaced closed longitudinal	165	2.6	5
Not displaced transverse	32	2.1	4
Displaced closed transverse	156	3.4	10
Do. excluding osteomyelitis	150	3.4	9
Displaced open transverse	118	4.6	19
Do. excluding osteomyelitis	105	4.5	14
Fractures complicated by osteomyelitis	20	9.5	34

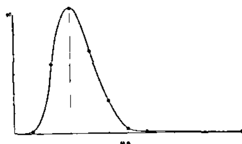
TABLE 3

Comparison between Control and Prospective Series of Displaced Open Transverse Fractures. Time in Months Required for Healing of 95 per Cent

	Healing time in months: Including osteomyelitis	Healing time in months: Excluding osteomyelitis
Control Series	20	14
Prospective Series	14	14

2. *Time as a geometric variable.* In Fig. 1 numbers of fractures observed to be healed plotted against the corresponding times produced a skewed curve. When a logarithmic time scale was used the resulting curve became symmetric (Fig. 2). If we conceive of the fracture groups as normally distributed around a central healing time then the distribution of numbers of healed fractures on either side of the central healing time can be interpreted as follows.

Let $\bar{t}$ be the central healing time and t_s the standard deviation of the healing time then in the logarithmic approach referred to in Fig. 2 an upper limit can be set to



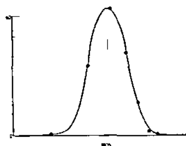


Fig 1 *Fig 2*

Fig 1 Healing of closed displaced longitudinal fractures. Time as a linear function

Fig 2 Healing of closed displaced longitudinal fractures Time as a logarithmic function

$$\log \bar{t} + \log t \;=\; \log (\bar{t} \quad t\,)$$

and a lower limit to

$$\log \bar{t} - \log t_s \;=\; \log (\bar{t}/t\,)$$

In the linear approach in Fig 1 the abscissa represents the anti logarithms of the quantities above or in terms of upper and lower limits

$$\bar{t} \quad t \quad \text{and}\; \bar{t}/t_s$$

and the value for central healing time is

$$\bar{t} = \sqrt{\bar{t} \quad t \quad \bar{t}/t_s}$$

The central healing time is thus the geometrical average between the two limits

The other groups of fractures also had this type of distribution and have been analyzed in a similar way The data for all groups fit reasonably well a straight line when plotted with time as a logarithmic function of the probits (Fig 3)

3 *The significance of the calculated healing time* The regression lines (Fig 3) show how the slope is flatter with longer healing times and how the 50 per cent (probit 5 00) and 95 per cent (probit 3.36) intercepts vary A difference between two groups consisting of a decrease in a limited number of cases with a very long healing time will not influence the average healing time particularly but will change the distribution In the graphs—compare displaced open transverse fractures including and excluding osteomyelitis in Fig 3—this is reflected by a minor change in the 50 per cent value and an obvious change in the 95 per cent value The central healing time is relatively constant while the regression line is changed to intercept with the 95 per cent level about 5 months earlier Thus the 95 per cent value provides a measure for studying minor extreme subgroups in the group which clinically have not been rated separately The same example illustrates how such a subgroup with common clinical criteria (osteomyelitis) can be separated from the main group resulting in a change in the 95 per cent healing time

For further information on this method the reader is referred to *Moore et al* (1951) and to *Hoffmann* (1963)

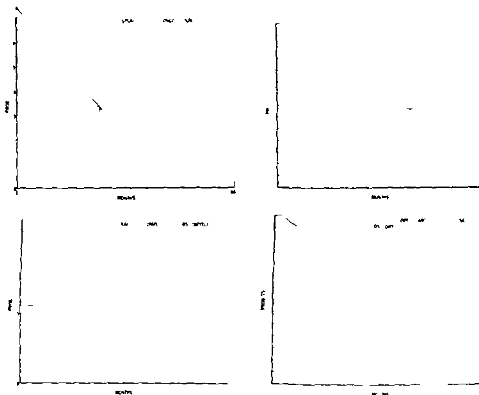


Fig. 3

Examples of graphs used for derivations of healing times. Broken lines are the coordinates for the point of interception of the 50 per cent and 95 per cent levels.

RESULTS

The healing times for different types of fractures as derived from the type of graph shown in Fig. 3 have been listed in Table 2. Longitudinal and transverse fractures show large differences in healing time. There is also a difference between open and closed transverse fractures which is considerably reduced after removal of osteomyelitis cases from both groups. Only two out of 22 cases of osteomyelitis were subjected to amputation before clinical union had occurred. Therefore it was possible to estimate healing time in this group as well. Osteomyelitis can be shown to double the time for healing for 50 per cent as well as for 95 per cent of the cases compared to the time for healing of open transverse displaced fractures without osteomyelitis.

Undisplaced fractures even if transverse show the shortest healing times of all.

A comparison between control and prospective series showed a longer healing time of open transverse fractures in the former series (Table 3) A large difference in the incidence of osteomyelitis between these series was observed (*Edwards* 1965) Removing osteomyelitis cases from both series accounted for the difference observed in healing time

DISCUSSION

Healing of 95 per cent of the group of closed longitudinal frectures required five months *Ellis* (1958) referred to cases not healed at this time as delayed union As shown above the anatomical type of fracture skin injury degree of displacement and infection influence the pattern of healing time Therefore closed longitudinal fractures are not a standard for normal healing time unless the composition of the material is considered As union may be delayed by causes which are clinically apparent it seems reasonable that healing of a fracture should not be considered delayed until the 95 per cent time period for the type of fracture has elapsed

As shown in Table 3 no difference could be demonstrated between the control and prospective series of open transverse fractures after removal of osteomyelitis cases In the prospective series 13 out of 46 cases of open transverse fractures without osteomyelitis underwent secondary treatment for slow union compared to 5 out of 58 cases in the control series This treatment seems to have had a negligible effect on Healing time

From comparison of the two series it is apparent that the best means of improving rate of fracture healing was the prevention of bone infection

SUMMARY AND CONCLUSIONS

The healing time of a large series of fractures of the shaft of the tibia was studied by probit analysis

1) The incidence of healing in the different groups of fractures can be regarded as normally distributed in relation to time as a geometric variable

2) Fractures of different etiological and anatomical types show large differences in healing time and an analysis of healing time must take this fact into account

3) Fractures complicated by osteomyelitis are normally distributed in relation to a healing time which is exceedingly long

4) Comparison between open transverse displaced fractures treated with and without particular attention to the skin injury show that the difference in healing time is due to a difference in the incidence of osteomyelitis

5) Secondary surgery for cases considered to have slow union has no demonstrable effect on healing time in cases without osteomyelitis

6) It is suggested that the limit for delayed union should be defined as the time when healing of 95 per cent of the corresponding group has occurred

RÉSUMÉ ET CONCLUSIONS

Le délai de guérison d une large série de fractures du corps du tibia a été étudié par analyse de la probabilité

1) L incidence de guérison dans les différents groupes de fractures peut être considérée comme normalement répartie en relation avec le temps comme une variable géométrique

2) Les fractures de type étiologique et/ou anatomique différent montrent de grandes différences dans les délais de guérison et une analyse du délai de guérison doit tenir compte de ce fait

3) Les fractures compliquées d ostéomyélite sont normalement réparties par rapport à un délai de guérison qui est extrêmement long

4) Une comparaison entre les fractures déplacées transversalement traitées avec ou sans attention particulière à la plaie de l épiderme montrent que la différence du délai de guérison est due à une différence dans l incidence de l ostéomyélite

5) Une intervention chirurgicale secondaire dans les cas considérés comme ayant une soudure lente n a pas d effet manifeste sur le délai de guérison dans les cas sans ostéomyélite

6) Il est suggéré que la limite d une soudure retardée doit être déterminée comme le temps nécessaire à la guérison de 95 pour cent du groups correspondant

ZUSAMMENFASSUNG UND SCHLUSSFOLGERUNGEN

Die Heilungsdauer einer grossen Reihenfolge von Tibiaschaftbruchen wurde mittels Probitanalyse studiert

1) Das Auftreten von Heilung bei den verschiedenen Gruppen von Brüche kann als normal verteilt in Beziehung zur Zeit als eine geometrische Variable angesehen werden

2) Brüche verschiedener äthiologischer und/oder anatomischer

Typen zeigen weitgehende Verschiedenheiten der Heilungsdauer und eine Analyse der Heilungsdauer muss diese Tatsache in Betracht ziehen

3) Durch Osteomyelitis komplizierte Bruche sind normalerweise verteilt hinsichtlich einer Heilungsdauer die ausserordentlich lang ist

4) Ein Vergleich zwischen offenen verschobenen Querbrüchen die mit und ohne besondere Beachtung der Hautbeschädigung behandelt wurden zeigt dass die Verschiedenheit in der Heilungsdauer mit der Verschiedenheit im Auftreten von Osteomyelitis zusammenhengt

5) Sekundare Chirurgie in Fallen mit verspäteter Heilungstendenz hat keinen nachweisbaren Effekt auf die Heilungsdauer in Fällen ohne Osteomyelitis

6) Man schlägt vor dass die Grenze fur verspätete Heilungsdauer als die Zeit bezeichnet werden sollte in der 95 Prozent einer entsprechenden Gruppe geheilt sind

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Announcements

ÖSTERREICHISCHE GESELLSCHAFT FÜR UNFALLCHIRURGIE

Anlässlich des 80. Geburtstages von Herrn Prof. Dr. *Lorenz Bohl*
wurde in Wien die österreichische Gesellschaft für Unfallchirurgie g
grundet.

Ziel der Gesellschaft ist es, einerseits sämtliche Fachärzte für Unfal
chirurgie in Österreich zusammenzufassen, andererseits aber auch e
gemeinsames Forum zu schaffen, auf dem Unfallchirurgen des In- ur
Auslandes sowie jene Fachärzte anderer Fachrichtungen, die sich m
unfallchirurgischen Problemen befassen, ihre Erfahrungen austausch
können.

Der erste Kongress der Gesellschaft findet am 16. und 17. Oktob
1965 in Salzburg statt. Dabei werden die Vorderarmschaftbrüche na
folgender Einteilung abgehandelt:

1. Vorderarmschaftbrüche frisch geschlossen
2. Vorderarmschaftbrüche frisch offen
3. Vorderarmschaftbrüche infiziert,
4. Vorderarmschaftbrüche mit verzögerter Heilung
5. in Fehlstellung geheilte Vorderarmschaftbrüche
6. Vorderarmschaftpseudarthrosen

Vortragsanmeldung zu diesem Thema sowie freie Vorträge sind
30. Juni 1965 an das Sekretariat der österreichischen Gesellschaft f
Unfallchirurgie z. H. Herrn Dr. *Erich Jonasch*, Webergasse 2, Wien
zu richten.

The Brazilian Society for Surgery of the Hand will sponsor the 1st International Congress of Hand Surgery will be held between July 19-21—1965—at the Hotel Gloria Rio de Janeiro Brazil

Any information concerning the meeting will be obtained thru:

Odilio Silva General Secretary Sociedade Brasileira de Cirurgia da Mão Avenida Churchill 97 – 10 ° Rio de Janeiro – Est. Da Guanabara – Brasil

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Die *Gesellschaft fur Wirbelsaulenforschung* schreibt einen

GEORG SCHMORL PREIS

aus der alle 2 Jahre fur eine hervorragende Arbeit aus dem Gebiet der Wirbelsäulenforschung verliehen werden soll

Die Gesellschaft fordert alle jungen Wissenschaftler die auf diesem Gebiet tätig sind auf Manuskripte oder Arbeiten die im letzten Jahr erschienen sind bis zum 31. 7. 1965 an den 1. Vorsitzenden Prof *Junghanns* Frankfurt/M Unfall Krankenhaus Friedberger Landstrasse einzureichen

Acta orthop Scandinav 36 115–126 1965

From the Orthopaedic Department University Hospital Lund
Chief Professor Gunnar Wiberg and The Department of Pathology Lund
Chief Professor C. C Ahlstrom and The Department of Pathology II Uppsala
Chief Professor B Engfelt

METAL IMPLANTS IN THE HUMAN BODY

A Histopathological Study

By

HANS EMNÉUS and UNNE STENRAM

Most implants used in orthopaedic surgery are of metallic origin Metals and alloys employed during the last 20 years are as a rule tolerated by the human body for several years though they always evoke a foreign body reaction

Metallic implants can produce the following side-reactions in the contiguous tissue

1 Mechanical or physical irritation
2 Chemical or electro chemical irritation
3 Oligodynamic or catalytic effect
4 Carcinogenic effect

Our knowledge of the last two types (3 and 4) of reaction is very meagre Experimental investigations have shown that metal implants can induce neoplasms in rats mice and hamsters (*Oppenheimer et al* 1956 *Oberling* 1959 *Kaplan* 1959) Despite some case reports (*Schinz* 1942 *Mc Dougal* 1956) long experience has taught that such reactions are extremely rare in man and may therefore be ignored

Though much has been written about reaction 1 and 2 in experimental animals the literature on these effects in man is scanty *Zierold* (1924) and *Key* (1946) discuss some problems of this type

At autopsy of all together 13 cases *Collins* (1953) studied the structural changes of human bone around collum nails and plates with screws of stainless steel He found no corrosion of the steel (18–8) but only what he considered a more or less mechanical reaction of the tissue The possibility of a chemical reaction was not discussed It is

now known (*Emneus* 1961) that 18–8 steel often corrodes and thereby makes a chemical reaction with the surrounding tissue likely. The reaction of the soft tissue is important, especially around plates and screws, wires and nails projecting into the surrounding soft tissue.

Baeckstroem & Block (1953), *Cater & Hicks* (1956 and 1962) and *Hicks* (1958) investigated cases where metals had caused abscesses or chemical irritation and discussed the problem very thoroughly.

Emneus (1957) reported cases with supposedly electro-chemical tissue reaction and described the histopathological picture. *Cohen* (1959) published a detailed account of a fatal case of supposedly electrolytic origin. *Scales et al* (1955, 1956 and 1959) have given much attention to the subject but their papers include no systematic description of the histopathology. Tissue reaction around nylon prostheses were thoroughly investigated by *Scales* (1957). Most of these papers concern cases where chemical reaction was suspected. Knowledge of the normal or average tissue reaction can be obtained only from the previously mentioned autopsy studies. According to *Hicks* (1958) evidence of iron pigment is often demonstrable around vitallium implants but not of chemical intolerance.

In view of the fragmentary nature of our knowledge of the effects of metal implants on contiguous tissue we decided to examine soft tissue biopsies from cases where the clinical course strongly suggested mechanical or chemical irritation, and from cases where the implants were removed for prophylactical reasons and cases in which treatment of a fracture with a metal implant failed because of factors that could not be ascribed to the implants on clinical grounds.

MATERIAL AND METHODS

The biopsy material consisted of almost all cases seen at the department of orthopaedics in the years 1956–1962 with obvious clinical symptoms of mechanical and/or chemical irritation. A few outstanding severe cases of massive bone absorption caused by mixed appliances (steel + vitallium) referred to us from elsewhere are not included in the material. The biopsies from cases where the implants were extracted for prophylactic reasons were selected at random from a total of 238 cases seen during the same time period. The group of non-healing fractures consisted of cases of fractures of the femoral neck with necrosis or pseudarthrosis where *MOORE* arthroplasty or osteotomy was made.

The biopsies were taken where the reaction, if any, seemed to be most pronounced. Most of the biopsy specimens were taken by one (*Hans Emneus*) of us. The specimens were as a rule the size of a hazel nut or a walnut. They were immediately fixed in 10 per cent formol. Sections were stained with hematoxylin-eosin and the

Turnbull blue method. With the latter method ionized iron stains blue. Ionized cobalt stains dark-brown and ionized nickel gives a yellow precipitate with potassium ferricyanide. Ionized chromium is green but gives no precipitate with potassium ferricyanide (*Emneus Petersen* 19[illegible]). Pigment that turned blue when treated with this method is called Turnbull positive pigment, all other pigments Turnbull negative. So-called formalin pigment was dissolved and removed from the sections before staining, as in our previous studies (*Emneus & Stenram* 19[illegible]). The amount of pigment, when present, was subjectively evaluated and classed as — to +++ (Tables 1 and 2).

Table 1 comprises simple implants such as screws, pins or nails, and Table 2 compound implants such as screws and plates, while Table 3 covers all the implants. The groups in the table are:

Group 1. Prophylactically extracted implants. Patients with healed fractures with no complaints at all. They had only a screw, pin, plate or all three, and were offered extraction.

Group 2. Cases where fracture treatment failed for reasons not clinically related to the osteosynthetic materials.

Group 3. Cases with clinically obvious mechanical irritation, i.e. hip nails or Kuentscher nails and Rush pins projecting into the musculature or adjacent tissue. In this group co-existing chemical irritation was considered unimportant.

Group 4. Cases with clinically obvious chemical irritation, co-existing mechanical irritation was considered unimportant. An abscess with abundant pus was seen in 13 out of 21. The pus was sterile in 5 cases. Culture gave growth of non-pathogenic Staphylococcus albus in 2 and of Staphylococcus aureus sensitive to all antibiotics in 4. In 2 cases culture was not done. All 13 healed by first intention after extraction of the implants.

In the remaining 8 cases there was spontaneous pain, swelling, tenderness and rarefaction of bone but no purulent liquefaction. Symptoms ceased after extraction of the implants. The interval between insertion and onset of symptoms ranged from 6 weeks to 8 years (average 22 months).

OBSERVATIONS AND COMMENTS

All biopsies showed a small amount of fibrous tissue around the implants with a rather small number of lymphocytes and fibrocytes and a few macrophages and occasionally giant cells. In this respect the specimens differed but slightly.

The amount of pigment in the tissues varied considerably from case to case (Tables 1–3 and Figs. 1–2). There was nearly always Turnbull positive pigment.

Turnbull negative pigment was sometimes seen around the implants. As formalin pigment had been dissolved and removed from the sections the Turnbull negative pigments most probably originated from the implants, either as a transfer from instruments during the operation or dissolved by corrosion. Since clinical evidence of chemical irritation

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ingle *Screw Pin or Wire*

Non phagocytized pigment											
Turnbull pos					Turnbull neg						
−	+	++	+++	++++	−	+	++	+++	++++		
	1	1				1					
		1	1			2					
		1				1					
	1										
			1			1					

Table 1 2 and 3

Group 1 Prophylactically extracted implants Patients with healed fractures with no complaints at all They had only a screw pin plate or all three and were offered extraction

Group 2 Cases where fracture treatment failed for reasons not clinically related to the osteosynthetic materials

Group 3 Cases with clinically obvious mechanical irritation *i e* hip nails or Kuentscher nails and Rush pins projecting into the musculature or adjacent tissue In this group co existing chemical irritation was considered unimportant

Group 4 Cases with clinically obvious chemical irritation co-existing mechanical irritation was considered unimportant An abscess with abundant pus was seen in 13 out of 21 The pus was sterile in 5 cases Culture gave growth of non pathogenic Staphylococcus albus in 2 and of Staphylococcus aureus sensitive to all antibiotics in 4 In 2 cases culture was not done All 13 healed by first intention after extraction of the implants

Vitallium is Co Cr Mo-alloy

Steel is Cr Ni and Cr Ni Mo steel *i e STAINLESS STEEL*

We have decided not to deal with metallurgy in this paper The osteosynthetic materials of stainless steel used in this investigation are of Scandinavian British American and possibly German origin

We have very much to say about corroding metals However this paper is not devoted to the etiology of corrosion but the metal pigmentation of tissues and its relation to the strength and type of foreign body reaction

TABL
Compound Implants i

	Number of cases	Phagocytized pigment									
		Turnbull pos					Turnbull ne				
		−	+	++	+++	++++	−	+	++	+++	++++
Group 1											
Vitallium	8	1	3	4				1			
Steel	*10*		*5*		*3*	*2*		*4*			
Group 2											
Vitallium	6	2	2	2					2		
Steel	*3*		*1*	*1*	*1*				*1*		
Group 3											
Vitallium	4	1	1	2				2			
Steel	*3*		*1*	*1*	*1*			*1*			
Group 4											
Vitallium	7		1	5	1			1			
Steel	*13*		*2*	*2*	*3*	*6*		*1*	*1*		

TABLE
All Implants i

	Number of cases	Phagocytized pigment									
		Turnbull pos					Turnbull neg				
		−	+	++	+++	++++	−	+	++	+++	++++
Group 1											
Vitallium	14	1	7	6				1	1		
Steel	*23*		*13*	*2*	*6*	*2*		*6*			
Group 2											
Vitallium	17	3	5	9				1	3		
Steel	8		3	2	3				1		
Group 3											
Vitallium	9	1	6	2				2			
Steel	*17*	*1*	*10*	*3*	3						
Group 4											
Vitallium	8		1	5	2			1			
Steel	*17*		*3*	*4*	4	*6*		*1*	*1*		
Total	113										

9
Screw or Pin and Plate

Non pha cyt d pi m nt											
Turnbull po					Turnbull n g						
−	+	++	+++	++++	−	+	++	+++	++++		
	1	2	1	1		4					
		2					1				
		1	1				1				
	2										
		1	4	4		3	5				

3
the whole Material

Non pl ocyti l pigm nt									Col ur of th Turnbull ne p m nt	
Turnbull po				Turnbull n g						
+	++	+++	++	−	+	++	+++	++++	Black	Brown or gre n
	1								1	1
	4	1	1		5				2	8
									2	1
	3	1			9	1			1	2
1										2
1	9	1			1	1				2
1										1
1	1	5	4		3	5			1	7

Fig 1

Fig 2

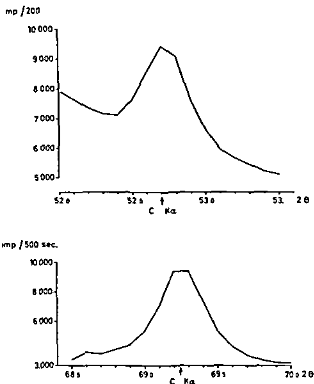


Fig 3

X ray fluorescence curve for cobalt (upper diagram) and chromium (lower diagram) The analysis was made on a piece of tissue along a McLaughlin nail and plate of vitallium that was extracted because of mechanical irritation The X ray intensity of Co/Cr is about 5/? which corre ponds to their proportions in the vitallium alloy

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Figs 1 and 2

Hist logical sections of two different biopsies The sections were stained according to the Turnbull blue metho l All pigment appears black in the photographs Each photograph co ers al out one fourth of the section and shows about one fourth of the pigment present in the sections × 115 In the biopsy shown in *Fig 1* the pigment was evaluated as phagocytized Turnbull positive pigment + The larger dots re present the pigment The bi psy shown in *Fig 2* was evaluated as phagocytized Turnbull positive pigment ++++ non phagocytized Turnbull positive pigment ++++ non phagocytized Turnbull negative pigment + Large accumulations of non phagocytized pigment are seen in the upper part of the picture and in the right half of the middle part while most of the pigment in the lower part of the picture is phagocytized

The presence of Turnbull positive pigment around vitallium implants may be explained in several ways

1. It may derive from corrosion of vitallium which contains 0.5–1 per cent iron as a contamination
2. Iron from steel tools, screws, drivers, drills and guide wires used during the operation can be transferred to the implants (*Bowden et al* 1955)
3. It may be a sequal of bleeding during the operations

Surprisingly, Turnbull negative pigment is more often seen around steel than around vitallium implants. However, the steel is an alloy containing Fe, Ni, Cr and Mo. These elements may be dissolved from the corroding implants or possibly be scraped off during the operation.

From what has been said above and from our previous experimental studies (*Emneus* 1960, 1961, *Emneus & Stenram* 1960, *Emneus & Baecklund* 1960), it appears that Turnbull negative pigment and large amounts of Turnbull positive pigment, especially when non-phagocytized and situated close to the implants, indicate corrosion and chemical irritation. But such pigment may exist in the tissue around steel implants without any accompanying clinical symptoms or signs of chemical irritation (Tables 1 and 2). Vitallium shows the same tendency though not so marked. The reason is most probably that corrosion exists without producing obvious clinical signs. The cases showing the strongest clinical evidence of chemical irritation, however, always showed large amounts of non-phagocytized pigment. It thus appears that corrosion of an implant is one of the causes of chemical irritation. It cannot be excluded from a clinical study of the present type that transfer metal from tools used can also cause chemical irritation.

SUMMARY

The material consisted of clinical cases where metallic implants were extracted for prophylactic reasons or due to failure of the fracture to heal, mechanical irritation or, as judged clinically, chemical irritation. The soft tissue around the implants was examined by histological methods including the Turnbull blue method for ionized iron. In several cases Turnbull negative pigment and large amounts of Turnbull positive pigment were found, often non-phagocytized and situated close to the implants. It is suggested that the pigment is due to corrosion of

the implants Corrosion sometimes causes clinically obvious chemical irritation The transfer of metals from tools used may also be a cause of tissue pigmentation

RESUMÉ

Le materiel d observation se compose de cas cliniques chez lesquels des implants metalliques ont été extraits pour des raisons prophylactiques par suite du défaut de guerison de la fracture d une irritation mecanique ou selon ce que l on a pu juger cliniquement d irritations chimiques Le tissu mou autour des implants a été examiné par des methodes histologiques y compris celle du bleu de Turnbull pour le fer ionise Dans plusieurs cas le pigment Turnbull negatif et de larges quantités de pigment Turnbull positif ont ete trouves souvent non phagocytes localisés a proximite des implants Il est suggere que le pigment est du a la corrosion des implants La corrosion cause parfois une irritation chimique cliniquement observable Le transfert des metaux des instruments utilises peut aussi etre la cause de la pigmentation du tissu

ZUSAMMENFASSUNG

Das Material bestand aus klinischen Fallen in denen metallische Implantate aus prophylaktischen Gründen oder wegen mangelnder Bruchheilungstendenz infolge mechanischer oder auch bei klinischer Beurteilung chemischer Irritation entfernt wurden Die Weichteile um das Implantat wurden mittels histologischer Methoden einschliesslich der Turnbull Blaumethode fur ionisiertes Eisen untersucht In mehreren Fallen wurde Turnbull negatives und grosse Mengen von Turnbull positivem Pigment gefunden das oft nicht phagozitiert und dicht am Implantat gelegen war Man nimmt an dass das Pigment durch die Zersetzung des Implantates entsteht Zersetzung ruft manchmal klinisch eine deutliche chemische Reizung hervor Die Überfuhrung von Metallen von den Werkzeugen die gebraucht wurden kann auch eine Ursache der Gewebspigmentation sein

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DELETERIOUS EFFECTS OF CORTICOSTEROIDS ADMINISTERED TOPICALLY, IN PARTICULAR INTRA ARTICULARLY

By

LIS ZACHARIAE

INTRODUCTION

Cortisone and its derivatives exert an indubitable clinical effect in rheumatoid arthritis and other disorders of the mesenchymal tissues both when administered systematically and topically One of the conditions in which topical treatment has gained most ground is osteoarthritis At the outset numerous reports were published on the excellent therapeutic effect (*Hollander* 1951 1953 *Kearsley* 1952 *Egelius* 1953 *Zachariae* 1954 and many others) Gradually however various complications began to be noticed first infections and their sequelae but more important still are the degenerative conditions which may develop in such a cortisone treated joint *Chandler et al* in 1958 reported Charcot like changes in a hip joint treated with local injections of hydrocortisone acetate and others have subsequently published similar findings (*Chandler & Wright* 1958 *Sweetnam et al* 1960 and *Steinberg et al* 1962) The author will report a few of her own cases which illustrate these changes and thereafter on the basis of the previous and present experience try to arrive at an acceptable explanation by considering the essential mechanism of the effect of these hormones

CASE REPORTS

Case I A male aged 68 had been suffering for one year from osteoarthritic symptoms with moderate radiological changes (Fig 1) In the course of the next year he received 50 injections of various cortisone preparations into the hip and at the same time systemic Butazolidin medication This resulted in temporary improvement which was however replaced by exacerbation and X rays showed that



Fig 1 Fig 2

Fig 1 (Case 1) Hip with moderate osteoarthritic changes
Fig 2 (Case 1) Same hip one year later Severe destruction of the femoral head has occurred during topical cortisone therapy

the lesion had become considerably worse with destruction and dislocation of the femoral head (Fig 2)

Case 2 A female aged 57 Ever since youth she had suffered from symptoms in both hips mainly the right When the medication was instituted X rays revealed subluxation and incongruence of both hips with distinct osteoarthritic changes on the right while on the left there was but moderate osteoarthritis She received a series of hydrocortisone acetate injections into both hips After one of the injections into the left hip she developed violent pain which persisted and became intensified making the left hip more painful than the right Seven years later the patient was so disabled that she was unable to walk X rays now showed that the lesion in the right hip had progressed steadily while in the left hip there was extensive destruction in fact the entire upper part of the femoral head had been destroyed

Case 3 A female aged 60 with a long history of various articular symptoms As she began to suffer from increasing pain in the right hip and X rays revealed osteoarthritis she was given one intra articular injection of hydrocortisone acetate This elicited severe pain which persisted and X rays 6 months later showed marked progression of the lesion

Case 4 A female aged 75 had increasing osteoarthritic complaints from one knee Within a couple of years she received repeated injections of hydrocortisone acetate The injections were administered in part intra articularly and in part at the pes anserinus which was tender (Fig 3) The symptoms persisted and X rays revealed a progressing lesion at the medial tibial condyle (Fig 4) Operation showed a small detached chip of bone to which the medial semilunar cartilage was attached Both were removed but without major effect upon the complaints



Fig. 3



Fig. 4

Fig. 3. (Case 4.) Knee joint shortly after the institution of topical hydrocortisone acetate therapy.

Fig. 4. (Case 4.) Same knee 6 months later, after several topical injections of hydrocortisone acetate, showing a progressing bony lesion at the medial tibial condyle.

DISCUSSION

These case histories illustrate the degenerative changes which may develop in joints treated topically with cortisone preparations and which do not differ from those reported previously in the literature. However, the author has tried to report a few typical examples which will be discussed below. That such complications may occur must be considered definitely proved, and it now remains to find the explanation and to decide whether it is justified at all to treat osteoarthritis with topical injections of cortisone. *Hollander*, who has a wide experience of this treatment, reported in 1960 that about 1 per cent of the treated joints became unstable. This might be due to the disease itself, as the ligaments had been stretched for so long by effusion in the joint, but it might also have been caused by the treatment.

Chandler et al. (1958, 1959) interpret these degenerative changes as being of the "Charcot type", i.e. that cortisone renders the joints painless, so that they are more apt to get worn. In a study from 1958

Chandler & Wright found radiological evidence of deterioration in 13 out of 25 knee joints after treatment with hydrocortisone acetate or hydrocortisone tertiary butyl acetate On comparing these two groups they found in the one showing radiological exacerbation after the treatment a significant improvement in walking time and an alleviation of pain somewhat but not significantly greater than in the group showing no radiological exacerbation This supports the Charcot theory *Sweetnam et al* (1960) incline to this theory while *Steinberg et al (1962)* express *doubt In their opinion the analgesic effect of the* cortisone preparations is not marked enough for such a mechanism but they are unable to suggest a better explanation

In the present cases there was no striking relief of pain so that Chandler s theory is probably not applicable in this series

The purely mechanical traumatic effect which may be exerted by the injection of a crystalline substance should not be under estimated In Case 4 a purely local necrosis occurred after sub periosteal injection and Case 3 developed a local necrosis of the femoral head after one painful injection which may simply have injured a vessel and caused an infarction Case 1 received 50 topical injections in one year and this may be imagined to harm any joint A few of the named complications may simply be traumatic but it has been clearly demonstrated by the studies of *Chandler & Wright* (1958) and by the present investigations that in the great majority of cases they are probably due to another mechanism Any osteoarthritis progresses in jumps but presumably we need not consider the possibility that these degenerative changes might be due exclusively to this natural progression

How then do these cortisone preparations act in the joints? Various theories have been advanced but the problem cannot be considered as solved Cortisone preparations injected intra articularly disappear with striking rapidity from the synovial fluid However the prednisolone derivatives appear to linger somewhat longer (*Wall & Murdoch 1960) The explanation is partly that some absorption takes place to the entire* organism (*Shuster & Williams* 1961) and partly that the cortisone derivatives have to be transformed into certain metabolites to exert their activity (*Wilson* 1956)

In osteoarthritic joints the synovial fluid is abnormal the degree of polymerization of hyaluronic acid being much lower than in normal synovial fluid This has been demonstrated *int al* by *Sundblad* (1953) and *Kulonen* (1955) by viscosimetry *Hedberg & Moritz* (1958) demonstrated in tissue cultures that hyaluronic acid is produced by the cells

in the synovial membrane and in the periarticular tissue which contain numerous large mast cells (*Asboe Hansen* 1950 1951) In other words it must be presumed that under pathological conditions the synovial membrane produces a low molecular hyaluronic acid and that the injected steroids or metabolites thereof influence the cells to produce a more normal high molecular hyaluronic acid *Jessar et al* (1953) also feel that the hyaluronic acid in the most important fraction of the synovial fluid despite the fact that it is a relatively small fraction They found that hydrocortisone acetate exerted no effect upon the protein fraction in the synovial fluid while *Kulonen* (1955) did find certain changes in the synovial proteins following injection of hydrocortisone acetate The investigations of *Jensen & Zachariae* (1959) into the osmotic tension in the synovial fluid during treatment with hydro cortisone acetate supports the theory on the role of hyaluronic acid

The mechanism outlined above may explain part of the clinical analgesic effect of the cortisone derivatives since the accumulation of fluid subsides because the more high molecular hyaluronic acid binds less water so that tension and pain subside

Other studies on wound healing and formation of granulation tissue have demonstrated however that cortisone inhibits the new formation of connective tissue as the synthesis of ground substance is inhibited presumably through an action upon the mast cells which are prevented from producing normal hyaluronic acid (*Asboe Hansen* 1950 1952 *Moltke & Zachariae* 1954) On the face of it it would seem unlikely that the same cells could be favourably influenced in certain articular diseases and unfavourably in wound healing granulations by the same cortisone preparations This phenomenon might perhaps be imagined to be due to enzymatic processes but in treating osteoarthritis with cortisone preparations a given equilibrium would have to be obtained as an overdosage would give rise to the necrotic lesions illustrated by the previous reports and by the present case histories

Whether the essential mechanism of cortisone is one or the other it must be established that it inhibits the new formation of connective tissue *Ragan et al* (1949) were the first to demonstrate the inhibitory effect of cortisone upon the formation of granulation tissue and innumerable studies on this subject have been carried out since then Summing up it may be said that when administered systemically and even more when administered topically cortisone preparations exert their effect upon the mesenchymal tissue inhibiting its new formation (*Schiller & Dorfmann* 1957) Under the influence of cortisone the

tissue shows a reduced fibroblastic activity a reduced fibrocyte count inhibited endothelial regeneration inhibited formation of collagen fibrils and reduced vascularization In addition there will be a reduced capillary permeability a reduced leukocyte and macrophage count an action upon the reticulo endothelial cells and a reduced quantity of fibrin All this is possibly due to changes in the ground substance whose synthesis is disturbed (*Asboe Hansen* 1956)

In all tissues and in an osteoarthritic joint there is a constant degradation of tissue and simultaneous reparative processes *i e* building up of new connective tissue In a normal joint these processes are in equilibrium but in an osteoarthritic joint this equilibrium is disturbed for some reason or other At times the breakdown predominates resulting in the so called dry joints in which the cartilage gradually disappears at other times regeneration predominates resulting in the hypertrophic exudative varieties If corticosteroids are administered topically the regeneration but not the breakdown will be inhibited This may for a time be beneficial in the case of hypertrophic osteoarthritis Gradually however nothing is left but breakdown and the result is the complicating necrosis Although *Truela et al* (1953) believe that the symptomes and the articular changes in osteoarthritis are due rather to the reparative reactive hyperaemia produced by the primary cartilaginous degeneration than to these degenerative changes as such a certain amount of regeneration must be necessary at all times No doubt certain varieties of osteoarthritis would be highly suited for short or longer lasting treatment corticosteroids but how can we pick out these cases clinically and determine the dosage so that it accurately establishes the correct equilibrium between breakdown and regeneration?

In actual fact there are no doubt many different types of what we call osteoarthritis and it is a common finding that it is impossible to decide beforehand on the basis of the clinical features whether a patient is going to benefit by intra articular injections of cortisone derivatives It has been demonstrated that in osteoarthritis the joint temperature is elevated presumably because of hyperaemia (*Fleischer* 1954) During treatment with hydrocortisone acetate *Hollander* (1956) has studied the temperature in the knee joints of patients with osteoarthritis patients with rheumatoid arthritis and in a control group After the treatment he found a fall in the temperature in the group with rheumatoid arthritis a slight increase in the control group and a marked increase in the osteoarthritic group *Hollander* concluded that

changes in temperature depend upon the type of joint condition present To this may be added *Selye* s (1953) statements after applying the granuloma pouch technique in studying the effect of hydrocorticone upon tissues In his opinion there is a negative correlation between inflammation and necrosis meaning that the more an irritant stimulates to inflammation the more is the tissue protected against necrosis as inflammation is the defence reaction of the organism against the necrotizing agent Reversely if the protective inflammation is inhibited *e g* by cortisone there is a greater likelihood of tissue necrosis

This statement is in keeping with the clinical findings of *Jonash* (1962) Operating on a patient with bursitis who had received a total of 9 injections of hydrocortisone acetate during the preceding 7 months he found distinct changes in the surrounding connective tissue which was yellowish and showed on microscopic examination necrotic areas with mucoid degeneration

CONCLUSION

Cortisone preparations exert a clinically beneficial effect upon osteoarthritis but in a number of cases radiological exacerbation with degenerative articular changes results These changes are not explicable by the natural progression of the disease and only partially by the trauma caused by the injection A possible explanation is that cortisone renders the joints painless so that they will get more worn as Charcot joints but this is not the only possible explanation In osteoarthritis the normal equilibrium between degeneration and regeneration of tissue is disturbed In some cases degeneration predominates and in others regeneration Administration of cortisone which is known to inhibit the regeneration of connective tissue gives the degenerative processes a violent preponderance

SUMMARY

Four cases of radiologically demonstrable degenerative changes in osteoarthritic joints following topical application of hydrocortisone preparations are reported On the basis of previous publications and the present findings the author tries to elucidate the mechanism of this phenomenon The changes are probably not due to the natural progression of the disease but perhaps to some extent to the trauma of the injection especially in the event of numerous injections or injections into tight tissue Chandler s theory that the joints get severely worn because they have rendered painless by the injections is discussed It

is emphasized that cortisone is known to inhibit the new formation of connective tissue apart from exerting other possible specific effects on the joints The theory is advanced that cortisone, injected into osteo arthritic joints inhibits regeneration thus lending preponderance to the degenerative processes which constitute an important link in the disease

RESUME

Sont rapportes quatre cas de modifications degénératives demon strables radiographiquement dans des articulations osteoarthritiques a la suite de l application topique de preparations d hydrocortisone Sur la base de publications anterieures et des trouvailles presentes l auteur essaie d elucider de mecanisme de ce phénomene Les modifications ne sont probablement pas dues a la progression naturelle de la maladie mais peut etre dans une certains etendue au trauma de l injection specialement dans le cas de nombreuses injections ou d injections dans des tissus compacts Il est discute de la theorie de Chandler d apres laquelle il se produit une grave usure de l articulation du fait qu elle a ete rendue indolore par les injections Il est souligne que la cortisone est connue pour entraver la nouvelle formation de tissu conjonctif en plus qu elle empeche peut etre d autres effets spéfifiques sur l articula tion Il est avance la theorie que la cortisone injectee dans des articu lations osteoarthritiques entrave la regeneration donnant le prepon dérance au processus dégeneratif qui constitue un element important de cette maladie

ZUSAMMENFASSUNG

Über vier Falle von rontgenologisch nachweisbaren degenerativen Veranderungen in osteoarthitischen Gelenken die nach ortlicher Ver wendung von Hydrocortisonpraparaten auftraten wird berichtet Auf Grund vorangehender Veroffentlichungen und den gegenwartigen Be funden versucht der Verfasser den Mechanismus dieses Phanomens zu erklären Die Veranderungen sind wahrscheinlich nicht auf das natur liche Fortschreiten der Erkrankung zuruckzufuhren sondern vielleicht bis zu einem gewissen Grade auf das Trauma der Injektion besonder im Falle von zahlreichen Injektionen oder Injektionen in straffes Gewebe Chandlers Theorie dass die Gelenke aufs schwerste abgenutzt werden weil sie durch die Injektion schmerzlos werden wird diskutiert Es wird hervorgehoben dass das Cortison bekanntlich die Neubildung

von Bindegewebe hindert abgesehen davon dass es möglicherweise auch andere spezifische Wirkungen auf die Gelenke hat Die Theorie dass Cortison wenn in Gelenke injiziert die Regeneration hindert und somit zu einem Überwiegen von degenerativen Prozessen die eine wichtige Erscheinung der Krankheit darstellen führt wird aufgestellt

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TENDON TRANSFERENCE FOR ULNAR AND COMBINED ULNAR MEDIAN NERVE PARALYSIS

By

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The combined ulnar and median nerve paralysis usually results in the socalled *clawhand* (Fig. 1).

The etiology of this deformity includes various diseases of the nervous system as poliomyelitis, syringomyelia, Charcot-Marie-Tooth disease and in Eastern and African countries first and foremost *leprosy*. Also traumatic lesions play a role—overlooked or unsuccessful treated cases or cases in which surgical repair has been impossible due to the extension of the nerve damage, lesions of the brachial plexus etc.

The purpose of this paper is to present the—mainly—primary results of various forms of tendon transference made on 31 clawhands in 28 consecutive cases of leprosy operated at the Scandinavian Teaching Hospital in Seoul, Korea.

ANATOMY AND FUNCTION

To understand the mechanism of the development of the clawhand and its treatment it is necessary briefly to mention some anatomical facts and functional considerations.

Fig. 2 shows how the lumbrical and volar interosseous muscles are placed *volar* to the axis of the metacarpophalangeal joint and inserted in the extensor expansion in such a way that their action will be exerted *dorsal* to the axis of the interphalangeal joints.

Besides ab- and adduction of the fingers the intrinsic muscles are the prime flexors

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Fig 1
Clawhand due to leprosy

of the metacarpophalangeal joints and—synergistically with the long fingerextensors—extensors of the interphalangeal joints

If the metacarpophalangeal joints are stabilized in a position of 180 degrees or less the long extensors or the intrinsics *alone* are able to extend the distal two phalanges (*Fowler s* concept of fingerextension) Normally this stabilization is produced by the intrinsics In median ulnar nerve paralysis this function is lost and an attempt to open the hand fully will result in a more or less pronounced hyperextension of the metacarpophalangeal joints Because of this hyperextension the long extensors of the fingers are unable to exert their power on the distal two phalanges Deprived also of the extensor function of the intrinsics the interphalangeal joints will remain in semiflexed position

In grasping the flexion of the fingers starts in the interphalangeal joints and only when these are flexed is the flexion of the metacarpophalangeal joints carried out—resulting in a poor prehension

The median ulnar nerve paralysis does not always result in a claw hand deformity In the cases in which the capsule of the metacarpo phalangeal joint is tight or the interosseous muscles contracted preventing hyperextension of this joint the deformity will not occur This is quite in accordance with Fowler s concept

The *surgical correction* of the clawhand is mainly based on two different principles



Fig 2
Schematic drawing of the relation of the intrinsics to the axis of the finger joints

I An attempt to restore the function of the intrinsic muscles by tendon transference

II Prevention of hyperextension of the metacarpohalangeal joints by stabilizing these in 180 degrees or less

The logical treatment must be one which aims to restore the lost muscle function Stabilization of the metacarpophalangeal joints may reproduce the finger extension but not the action of the intrinsic muscles the only muscles which directly flex these joints

I *Restoration of the Function of the Intrinsic Muscles*

a) *Use of flexor sublimis as motor* Originally the method was worked out by *S Bunnell* The sublimis tendons are cut at their insertion on the base of the second phalanx split in two strands and transferred palmar to the transverse metacarpal ligament to the extensor aponeurosis on both sides of each finger The intrinsic muscles function as flexor of the metacarpophalangeal and extensor of the interphalangeal joints is usually well restored by this procedure while the abduction and adduction of the finger does not seem to improve considerably (*Brand* 1958) Later the method was modified somewhat (*Bunnell Littler Goldner Brand* and others) In stead of transferring all the sublimis tendons one or two are used and only inserted in one side of the aponeurosis of each finger

b) *Use of finger extensors* (*S Fowler* quoted by *D C Riordan*) Extensor indicis proprius and extensor digiti quinti are split in two strands These are passed through the interosseous spaces and inserted in the extensor aponeurosis It has been claimed that the result of this operation is merely caused by a tenodesis stabilizing the first phalanx However there is no doubt that an active muscle function is obtained—provided no tendon adhesion occurs (Duparc)

c) *Use of a wrist extensor* This method is described by *J W Littler* (1949) and in more detail by *P W Brand* (1958 1961)

Prolongation of extensor carpi radialis longus or brevis with a free graft and transference through the interosseous spaces or round the radial side of the forearm through the carpal canal to the extensor aponeurosis

II *Prevention of Hyperextension of the Metacarpophalangeal Joints*

Procedures of this type are based on the above mentioned concept of *Fowler*

a) *Bone block* A slab from the back of the knuckle is slid distal ward as a bone block (arthrorhisis) (L D Howard quoted by *S Bunnell*)

b) *Tenodesis* (D C Riordan) A strand from the tendon of extensor carpi radialis longus and one from extensor carpi ulnaris still attached to the base of the second and fifth metacarpal bone respectively are split—each of them—in two passed distalward through the interosseous spaces and sutured under tension to the extensor aponeurosis

c) *Capsuloplasty*—shortening of the volar capsule of the metacarpophalangeal joint (*F A Zancolli*, 1957) A simple surgical procedure in which a sort of duplication of the volar side of the capsule is made Both *Zancolli* and *P Buorrel et al* (1961) and *J Gosset* (1962) report satisfactory results using this method

SURGICAL TECHNIC

The surgical procedures used in our material are

1 One—split—sublimis tendon passed through the lumbrical canals 13 cases
2 Same procedure as above but with the use of *two* tendons 4 cases
3 Transference of extensor carpi radialis brevis (prolonged with a free graft) through the interosseous spaces 3 cases
4 Same procedure as 3 but with transference of the extensor tendon and graft round the forearm and through the carpal canal 11 cases

The technic used in group 1 and 2 has already been mentioned As a rule we have detached the 4th sublimis tendon unless special circumstances made the use of another tendon more convenient—as for instance a completely stiff or a partially amputated finger

The tendon is sutured under moderate tension the wrist kept in neutral position the metacarpophalangeal joints flexed 70–80 degrees the strand to the donor finger is intentionally made a little more slack

As the *transference* of a *wristextensor* to the *volar side* of the forearm (*Brand*, 1961) is less known and as it seems to be a very useful procedure the technic will be described in more detail

The tendon of the extensor carpi radialis longus or brevis is cut through a small incision 3–4 cm proximal to its insertion—in the cases reported here we used the radialis brevis but later on we changed to extensor longus as we gained the impression that this resulted in lesser weakening of the dorsal flexion of the wrist The tendon is withdrawn through another incision placed radially on the dorsal side of the fore



Fig 3

The tendon graft (m plantaris) passed through two slits in the widened part of the extensor carpi radialis longus

arm a little distal to the middle A third incision is placed on the volar side of the forearm midway between the former incision and the wrist —opposite the tendons of palmaris longus and flexor carpi radialis A tendon tunneller is pushed gently between these two tendons and beneath the brachioradialis muscle out through the incision on the dorsolateral side of the forearm The released extensor tendon is grasped and pulled down to the volar side

At this stage the anastomosis to the free graft is made As the graft we used palmaris longus a toe-extensor or the plantaris tendon

A 1–1½ cm longitudinal incision is made a little proximal to the cut end of the extensor tendon and this is opened to about the double of its original width The grafts are pulled through a small slit in the widened tendon and anchored by a few sutures on the "inside —if the

Fig 4
The tendon veil



a b

Fig 5
The finished anastomosis
a) From the anterior side
b) From behind



Fig 6

The four strands pulled through an incision right distal to the transverse capal ligament

plantaris tendon is available it is pulled out through another slit (Fig 3) forming an up-side down U The two edges of the "opened tendon are sutured with running suture The end of the tendon is cut obliquely to obtain a spindleshaped anastomosis In order to cover the raw surface of the cut end the proximal 2 cm of one of the grafts is transformed into a thin "veil by a forced pull on each side of the tendon by mean of a fine surgical forceps (eye forceps for instance) (Fig 4) The running suture started in the extensor tendon is continued distally closing the veil after this has been wrapped around the end of this tendon (Fig 5)

The two grafts (or the two ends of the plantaris tendon in case this has been used) are passed distally beneath the transverse carpal ligament and through an incision corresponding to the crease between thenar and hypothenar The grafts are split (Fig 6) and passed palmar to the transverse intermetacarpal ligaments and inserted in the extensor aponeurosis (Fig 7)

In all our cases whatever method was used the insertion was made

the unsatisfactory result was due to adherences reoperation with loosening of the adherences was done after which the function was excellent

Analysis of the Failures

7 cases—3 fair and 4 poor—must be regarded as failures In four of these the operations were unsatisfactory from a technical point of view—they were combined with other operative procedures which moreover resulted in difficulties as regards the postoperative re education One case was infected and for some unknown reason one did not receive any postoperative physical therapy The seventh case was a rather uncooperative man who probably never should have been operated

DISCUSSION

To secure a good result for the operation a meticulous preoperative muscle test is required—as in all kinds of tendon transference The condition of the extensor expansion should be paid special attention If an examination reveals that the degree of passive extension of the fingers exceeds the so called assisted extension (active extension of the interphaleangeal joints during external stabilisation of the metacarpo-phalangeal joints at 180 degrees or less—cf *Fowler*s concept)—it indicates a defect in the extensor expansion This must be repaired prior to any tendon transference or else the result will be disappointing

To restore the function of the important first dorsal interosseous muscle the tendon to the index finger ought to be inserted on the radial and not as here on the ulnar side of the finger However it has been found (*Brand Bourrel et al*) that a single insertion on the radial side of the indexfinger may result in a tendency to radial deviation of this finger whereas the index and third finger tend to stabilize each other in the pinch when the tendons have been inserted on the ulnar and radial side of the two fingers

The *tension* under which the tendons are sutured is of course of extreme importance This problem has already been dealt with above To secure proper tension *Brand* uses a metal splint on which the hand and fingers are placed (we found a small bowl of stainless steel—placed upside down—very convenient Fig 8) Even though this precaution is taken it is our experience that there is a tendency to pull the last sutured strands more tightly than the first ones, resulting in an im



Fig 8
The hand placed in the correct position for insertion of the tendon grafts

paired function of these Therefore the tension should be checked carefully by pulling the motor tendon while observing the fingermotion If the strands are sutured from the ulnar to the radial side a slight—overlooked—difference in tension will be less harmful because it will mainly concern the fifth finger

A disadvantage of the original Bunnell procedure is the tendency to develop the opposite deformity of the clawhand—the pill roller hand an intrinsic plus deformity The cause is that a strong muscle is removed from the flexor side of the proximal interphalangeal joint and transferred to the extensor side of the same joint sometimes resulting in a hyperextension of this joint The deformity which can be rather disabling does not develop in noticeable degree until 1–2 years have passed and may for this reason be overlooked It is especially in fingers with very mobile joints that this deformity occurs

As pointed out by *Bunnell* a flexion contracture of the proximal interphalangeal joint can occur if a stump of the cut sublimis tendon is left behind in the tendon sheath By attaching itself to the sheath proximal to the joint it will act as a sort of tenodesis This complication should be avoided by detaching the tendon close to its insertion

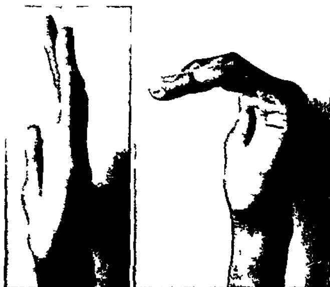


Fig 9

A clawhand 9 month after transference of the extensor carpi radialis brevis—prolongated by a free graft—through the interosseous spaces to the extensor expansion of the four ulnar fingers

The objections to the method in which a wrist extensor prolonged by a graft split in four strands is transferred through the interosseous spaces are that the grafts are apt to adhere so that the result will be merely a sort of tenodesis Moreover dorsiflexion of the wrist will result in a less powerful action of the transferred muscle Another draw back is that the postoperative re education is somewhat more difficult in these cases compared with the Bunnell operation Only three of our cases belong to this group—and all of them are satisfactory with active function of the transferred muscle (Fig 9)

In the cases in which the tendon is passed through the carpal canal a risk of crowding this may exist—so far we have not seen any signs of that In this connection we should like to draw attention to the importance of not placing the anastomosis between the extensor tendon and the graft at such a level that it finally will be situated beneath the transverse carpal ligament

A certain degree of weakening of the dorsiflexion of the wrist will occur by this method

Lucien Cornet et al (1962) report 20 cases in which the second and fourth sublimis are used to restore the intrinsics At the same stage the third sublimis is transferred to the thumb for restoration of the opposi

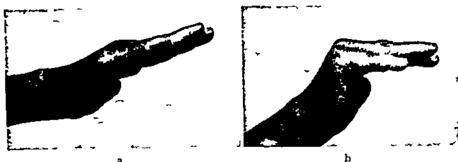


Fig 10

A clawhand 2 months after transference of the fourth sublimis tendon Note a slight tendency to hyperextension of the proximal interphalangeal joint of the fourth finger (b)

tion The primary results seem to be good Nothing is mentioned about development of intrinsic plus-deformity (it is not quite clear how long the observation period has been) *Bourrel et al* (1961) report 74 cases operated according to Bunnell s method using the sublimis tendons to the third and fifth finger Among these patients 18 were submitted to opponens plasty—probably also using a sublimis tendon (the technic not mentioned) At the follow up "interphalangeal hyperextension was met in 5 cases Of the 74 cases 20 had a "pre existing stiffness of the fingers In 30 cases nothing is mentioned One patient had a radial paralysis It must be supposed that at least the rest 23 patients had good mobility of the finger joints preoperatively It is most probable that *the five cases with interphalangeal hyperextension (that is intrinsic overaction!)* may be found in this last group counting 23 patients—a rather high percentage

So far we have not seen any cases of intrinsic plus deformity among our patients—but the time of observation is too short to state anything However we have noticed in a few cases of the "Bunnell type operation that the donor finger (Fig 10) has a tendency to hyperextension in the proximal interphalangeal joint—we have anticipated this "complication and as mentioned intentionally sutured the strand to the donor finger under a little less tension than the other fingers

However we feel that there is a definite risk for more disabling deformities in case two sublimis tendons have been detached from their insertion—maybe even a third one for opponens plasty! And—at least in hands with normal mobility of the finger joints—we would hesitate to use as many as three sublimis tendons for the reconstruction of the

finger function For the same reason we prefer Brand s method with the use of a wrist extensor as motor The fourth sublimis tendon can then be used if an opponens plasty is necessary

Some degree of intrinsic overaction should certainly be anticipated in other fingers than the donorfinger as in the cases in which an extensor is used as motor—simply due to the fact that the transferred muscle is more powerful than the muscles it is supposed to replace However there should be only little risk of a more pronounced deformity and impaired function because the flexors of the proximal interphalangeal joint are preserved

SUMMARY

The result of various forms of tendon transference for low ulnar and combined median ulnar nerve paralysis due to leprosy is reported

The material consists of 31 hands in 28 patients

The different principles and surgical procedures are mentioned and Brand s technic is described in more detail

With the disabling intrinsic plus deformity in mind the authors will not recommend procedures—advocated by some—in which not less than three sublimis tendons are detached from their insertion and used to restore the function of the intrinsics and the thumb Except cases with rather stiff joints the method of choice should be one that uses a wrist extensor extensor radialis longus as motor

RESUME

Est rapporte le resultat de differentes formes de transferts de tendons dans la paralysis due a la lepre du nerf ulnaire distal et des nerfs ulnaire et median combines

Le materiel d observation comporte 31 mains chez 28 malades

Les differents principes de la procedure chirurgicale sont mentionnes et la technique de Brand est decrite plus en detail

En pensant a l incapacité intrinsèque s ajoutant a la deformite les auteurs ne veulent pas recommander des procedures – défendues par certains – par lesquelles pas moins de trois tendons superficiels sont detaches de leurs insertions et utilises pour restaurer la fonction des muscles intrinseques et du pouce Excepte dans les cas ou les articulations sont assez regides la methode de choix doit etre celle qui utilise comme moteur un extenseur du poignet l extenseur radial long

ZUSAMMENFASSUNG

Über das Ergebnis von verschiedenen Formen der Sehnenuberpflanzung bei distaler Ulnaris und kombinierter N medianus ulnaris Lahmung wegen Lepraerkrankung wird berichtet

Das Material besteht aus 31 Handen von insgesamt 28 Patienten

Die verschiedenen Behandlungsprinzipien und chirurgischen Methoden werden erwahnt und die Technik von Brand wird eingehender beschrieben

Unter Beziehungsnahme auf die invalidisierende intrinsic plus Deformitet empfiehlt der Verfasser nicht ein Vorgehen das von einigen verteidigt wird bei dem nicht weniger als drei Sublimissehnen von ihrer Insertion gelost und zur Wiederherstellung der Funktion der kleinen Handmuskeln und des Daumens benutzt werden Mit Ausnahme von Fallen mit ziemlich steifen Gelenken sollte die Methode der Wahl in der Verwendung eines Handgelenksstreckers extensor carpi radialis longus als Kraftspender bestehen

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EPIDEMIOLOGY OF FRACTURES OF BONES OF THE FOREARM IN A MIXED SOUTH EAST ASIAN COMMUNITY, SINGAPORE

1 *A Preliminary Study*

By

P C N WONG

INTRODUCTION

The object of the present survey is

1 To determine the absolute incidence of fractures of the forearm in a mixed South East Asian Society and compare the findings with a European one Malmo (*Bauer* 1961 and *Alffram & Bauer* 1962)

2 To test further the hypothesis that fracture patterns may reveal how bone strength changes with age

3 To determine whether the dietary or hormonal environment or both have any influence upon fracture incidence patterns

4 To determine the role of race on fracture patterns

This survey is also a part of a South East Asian investigation into the role of Osteoporosis in the aetiology of fractures in the aged

It is believed this is the first epidemiologic survey of fractures of the forearm in a South East Asian community ever undertaken

It is to be emphasized that this is only a preliminary study and the work will be extended when further data become available

The survey follows closely the work of *Alffram & Bauer* (1962)

THE POPULATION AT RISK

Singapore with its mixed Asian Population of 1 445 929 where accurate knowledge of the Race age and sex of the community at risk is available presents unique opportunities for epidemiologic studies of fractures in a well defined community That part of the 1957 census

TABLE 1

Population of Singapore 1957 in Thousands

Detailed age group	Male	Female
0 – 4	136.7	128.0
5 – 9	112.0	106.1
10 – 14	71.2	65.1
15 – 19	70.1	65.5
20 – 24	61.3	58.0
25 – 29	59.8	52.0
30 – 34	50.1	39.8
35 – 39	46.5	36.2
40 – 44	43.0	33.2
45 – 49	37.8	28.9
50 – 54	29.3	22.5
55 – 59	20.6	16.9
60 – 64	12.0	12.3
65 – 69	6.8	8.6
70 – 74	3.4	5.3
75 and above	2.2	4.7

(which is the one used in this survey) showing the mixed population by sex and 5 year age groups is shown in Table 1

There is only one General Hospital in Singapore and all fracture cases are treated there

MATERIAL

The period under study is from 1962 to 1963 inclusive i e two complete years and the material consists of 1724 fractures of the forearm in 1711 patients The two annual totals of patients did not differ by very much being 852 and 872 respectively

Seven women and four men had bilateral Colles fractures and 2 boys had simultaneous bilateral displacements of the distal radial epiphysis

Only fresh fractures are included and pathological ones are not considered

Classification of Fracture Types (according to *Alffram & Bauer* 1962)

1 Distal fractures (1 034 cases) include fractures of the distal radius or ulna or both within 2 cms of the wrist joint

2 Shaft fractures of the radius or ulna or both (636 cases)

3 Proximal fractures of the radius (41 cases) include fractures of the neck of the radius (22 cases) and fractures of the head of the radius (19 cases)

Definitions (after *Alffram & Bauer* 1962)

1 Degree of Trauma

Moderate trauma is violence less than or equivalent to a fall to the ground from the standing position This includes falling from a chair or bed

Severe trauma includes all others e g falling from a height traffic accidents a fall downstairs etc

In the material collected it is possible to determine the degree of trauma in 6? per cent of the distal fractures 69 per cent of the shaft fractures and 76 per cent of the proximal radial fractures

2 Incidence of Displacement

Reduction of a fracture before immobilization means that the fracture was initially displaced whereas immobilization without reduction means there was no displacement or minimally so

The index of the incidence of displacement is defined as the ratio of the number of reduced over non reduced fractures In the material it is possible to determine whether the fractures are displaced or not in 69 per cent of the shaft fractures and 76 per cent of the proximal radial fractures

3 Age Specific Rates

These are calculated from the population figures (Table 1) as the annual incidence of fractures per 10 000 males or females in each 5 years age group

4 Sex Ratio

This is defined as the female divided by the male incidence

5 Male to Female Ratio

This is defined as the number of male fractures divided by the number of female fractures in a particular series

6 Children (boys and girls) are between the ages of 0 to 19 young adults 20 to 39 middle aged are those from 40 through 59 and aged are those 60 and above

RESULTS AND INFERENCES

Distal Fractures

Fractures of the distal radius or ulna or both (1034 cases) constitute 60 4 per cent of all fractures of the forearm (Table 2) 761 or 72 6 per cent males and 273 or 27 4 per cent are females The male to female ratio for the series is 2 8 In childhood this is 5 young adults 4 6 middle aged 1 3 and in old age it is 0 8

In both sexes the incidence reaches a peak in childhood (but is far less convincing among the girls) and drops to a minimum in young adults There is no similarity in the incidences in these two age groups fracture of the distal radius and ulna is predominantly a male disease (Fig 1)

There is a very gradual rise from the age of 40 onwards both sexes participating and with incidences in the various 5 year age groups which either are very close or identical and reaches a maximum in the 60s remaining more or less constant thereafter The peak does not reach the peak of infancy and childhood (Fig 1)

Compared with Malmo the incidence of the local boys is low In young adults and middle aged males the incidences correspond reasonably

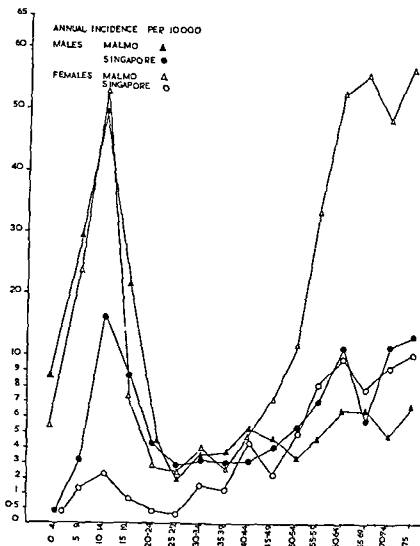


Fig 1

Annual male and female incidence of fractures of distal Forearm per 10 000 of population according to age in Singapore The Malmo incidences are superimposed

closely but in the aged the Singapore results are probably a little higher (Fig 1)

The local female results are completely different from those of *Alffram & Bauer* (1962) For girls and middle aged females these are markedly different from those of the corresponding ages in Malmo Nor is there the dramatic rise over the 20 year period from 40 to 60 as in the Swedish Community (Fig 1)

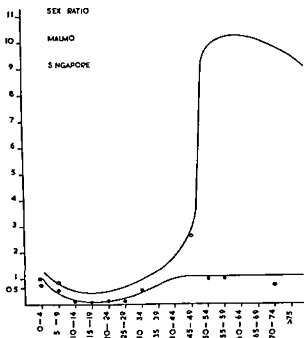


Fig 2

The ratio of female to male incidences of fractures of the distal Forearm in Singapore Malmo results are superimposed

The sex ratio is remarkably even in middle age and the aged but is in favour of the males in young adults and childhood again contrasting strongly with Malmo where the sex ratio was even in childhood and young adults but rising to about 10 during middle age and in the aged (Fig 2)

Severe trauma in the male except in the very young and the very aged is equal to or greater more common than moderate trauma in all other age groups This contrasts strongly with Malmo where only the young adults have severe trauma equal to or more common than moderate trauma In the females except in the 20–29 group moderate trauma prevails in all age groups (Fig 3)

Slipped Distal Radial Epiphysis

There are 37 slipped radial epiphyses in the material constituting 4 0 per cent of all the distal fractures (*cf* 3 9 per cent in Malmo) Two of the cases are bilateral Of the 37 cases only 2 are girls thereby giving a male to female ratio f 1/ to 1 (*cf* Malmo 2 4 to 1)

TABLE 2

Fractures of the Distal Radius or Ulna or both in Singapore 1962 63

Age	Male	Female
0 – 4	13	13
5 – 9	73	32
10 – 14	233	32
15 – 19	124	11
20 – 24	53	5
25 – 29	35	4
30 – 34	34	14
35 – 39	30	10
40 – 44	27	29
45 – 49	31	14
50 – 54	31	24
55 – 59	30	27
60 – 64	27	25
65 – 69	7	14
70 – 74	7	10
75 and above	6	9
Total	761	273

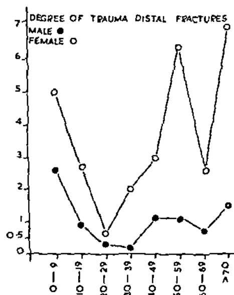


Fig 3

The ratio of severe to moderate trauma in fractures of the distal Forearm in Singapore

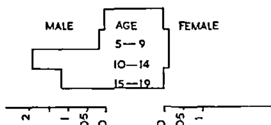


Fig 4

Annual incidence of slipped radial epiphyses per 10 000 of the Singapore population according to age and sex

The youngest is 8 and the oldest is 18

The annual incidence is low when compared to Malmo (Fig 4) Severe and moderate trauma are about even and reduction is necessary in all cases

Shaft Fractures

There are 636 fractures of the radius or ulna or both making up 36 6 per cent of the material under survey (Table 3) There are 512 (or 80 5 per cent) males and 124 (or 19 5 per cent) females The male to female ratio in the series is 4 1 1 In Malmo it is 2 1 More than ¾ (76 1 per cent) occur in children and thereafter in women it is rare In boys the incidence is a little less than ⅓ of that of Malmo but about 4 times that of the local girls The young male adults and middle aged males are comparable to but the aged incidence is perhaps a little higher than that in Malmo (Fig 5)

TABLE 3

Fractures of the Shaft of the Radius or Ulna or both in Singapore 19[illegible]-63

Age	Male	Female
0 19	38[illegible]	97
20 39	[illegible]3	14
40 59	40	8
60 and above	1	5
Total	51[illegible]	1[illegible]4

DISCUSSION

Although not convincingly so it would appear in the local material that the highest incidence of fractures of the distal forearm occurs in boys of the 10–14 age group the summit reached by the aged being a little below the peak attained by this group of boys

In spite of this however the injury is still the most common among the aged in men a little more so than in women

The survey has shown that the incidence of distal forearm fractures rises from 40 years onwards reaching a constant peak in the 60s both sexes participating but neither the rise nor the peak is as dramatic as that occurring among the women in Malmo

In women this rise is accompanied by an increase in the proportion of moderate trauma whereas among the men severe trauma continues to be equal to or in excess of moderate trauma until very aged The difference in trauma rate between the two sexes is explained by the fact that whereas there is an increased tendency to adopt a more sedentary existence with increase in age on the part of the female among men economic necessity often renders it essential even for the older ones to persist in heavy occupations and thereby to continue to expose themselves to the risks of such occupations

The data on distal forearm fractures among the females indicate clearly that the increase in fragility of the cancellous portion of the distal radius is small when compared with the women of Malmo

The increase in fragility with increase in age among the males is probably even smaller and the existing aged male fracture pattern is probably an expression of the failure of this group to adopt a more sedentary existence as they advance in years

The sex ratios in the fractures of the proximal radius also gives little evidence of any great increase in bone fragility among the men

In children cortical and cancellous fragility are about even but the latter increases with age more strikingly among the females (Fig 7) This merely indicates that the degenerative process in cancellous bone progresses with age more so in females than males and that cortical bone when once matured degenerates very slowly if at all

To explain the local mixed population fracture pattern and to ascertain reasons for the marked contrast between this and that of a European Community (Malmo) the following will be discussed

1 The factor of race
2 Exoskeletal factors which include accident proneness due to

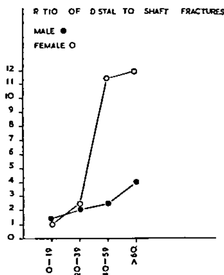


Fig 7
The ratio of distal to shaft fractures

physical defects commonly associated with the aged (*Buhr & Cooke* 1959) and severe trauma

3 Endoskeletal factors which include the anabolic steroid-osteoporosis relationship (*Reifenstein* 1957) and the role of diet

Race Factor

It is to be emphasized that the fracture pattern deduced in the present survey is that emanating from a mixed community consisting predominantly of three major and different races—Chinese and Malays (of Mongoloid composition) Indians (including Ceylonese) of a Caucasoid "Carpentarian" composition (*Del Tufo* 1949) That it should differ from one produced by a European Society (Malmo) consisting of a population with a uniform race is therefore not unexpected

There is strong evidence to support that skeletal structure is different in different races *Trotter et al* (1960) have shown that the skeleton of the American Negro (Negroid) is of greater density than that of the American White (Caucasoid)

Thus the differences between the European pattern (Malmo) of fractures and that emanating from a mixed South East Asian Community (Singapore) may therefore be a matter of race

Exoskeletal Factors

Accident proneness on account of the common physical defects associated with the aged (*Buhr & Cooke* 1959) increases the risk of fractures in this age group These exoskeletal factors no doubt operate with equal frequency in Singapore as elsewhere

Even thus fracture incidence among the local aged females is still remarkably small

There is evidence to show that severe trauma among the aged males may in part contribute to the coincidence of the fracture rates between the two sexes in this age group

The Anabolic Steroid osteoporosis Relationship

Reifenstein (1957) found in European Societies that which he ascribed on account of decline of anabolic steroids about the time of the Menopause osteoporosis in the aging women is approximately five times of that of aging men Even taking into consideration that severe trauma among men continues to be equal to or in excess of moderate trauma until the very elderly the incidense of fractures among the *older females in Singapore is very far from being five times that of the* corresponding males

Lugg & Bowness (1957) have shown that any differences in anabolic steroid excretion (17 ketosteroid) by the male subjects of the different ethnic groups (including Europeans) of Singapore could be regarded as reflections of differences in weight In the light of this evidence therefore it would not be unreasonable to assume that the anabolic steroid osteoporosis relationships of the local aging females are also analogous one with the other and with that of the European females as well Is then the local female fracture pattern another example of the lack of correspondence between osteoporosis incidence and fracture incidence? It may be that the local anabolic steroid osteporosis relationship is different (unlikely) and that the local fracture pattern is an expression of this difference

The Role of Diet

The caloric intake per capita per day in Singapore has been given as 2555 (*May & Jarcho* 1961) The diet is deficient in protein and is low in calcium (House hold Budget Survey Federation of Malaya 1957–1958) The given figure is a very optimistic estimate as it is certain that the more prosperous contribute considerably to this value It is

therefore reasonable to assume that in that portion of the population among whom fractures are rife the food intake is less, with the females the worse off (*Llewellyn Jones* 1962). If therefore diet alone is considered paramount in fracture aetiology it would not be unreasonable to expect the local female fracture incidence to exceed both the local male and also the Malmo female incidences. The Survey has shown that it is not so. Yet it is inconceivable that diet, in spite of *Bauer's* opinion (1960) to the contrary, can be dismissed in any discussion on fracture aetiology.

CONCLUSIONS AND SUMMARY

The survey has shown that:

1. Differences of fracture pattern between East (Singapore) and West (Malmo) is principally a matter of race influenced by environmental factors of which the most important is probably diet.

2. There is further evidence of the lack of correspondence between osteoporosis incidence and fracture incidence, thereby lending support to the hypothesis that osteoporosis and bone fragility may be different diseases (*Alffram & Bauer* 1962).

Whether the local pattern is normal or not, however, can only be known if epidemiological surveys are conducted upon similar racial groups living elsewhere under similar, better or more adverse environmental conditions (diet).

It can also be predicted from this study that when the same material is broken up into its racial components there will be as many fracture patterns as there are racial groups.

This work will be extended when more data become available.

RÉSUMÉ

L'étude a montré que:

1. Les différences dans les modèles des fractures entre l'Est (Singapour) et l'Ouest (Malmo) sont principalement une question de race fonction de facteurs environnants dont le plus important est probablement le régime alimentaire.

2. Le manque de corrélation entre l'incidence de l'ostéoporose et l'incidence de la fracture s'est avéré prêter appui à l'hypothèse que l'ostéoporose et la fragilité des os peuvent être des maladies différentes (*Alffram & Bauer* 1962).

De toute manière la question de savoir si le modèle local est normal

Exoskeletal Factors

Accident proneness on account of the common physical defects associated with the aged (*Buhr & Cooke* 1959) increases the risk of fractures in this age group. These exoskeletal factors no doubt operate with equal frequency in Singapore as elsewhere.

Even thus fracture incidence among the local aged females is still remarkably small.

There is evidence to show that severe trauma among the aged males may in part contribute to the coincidence of the fracture rates between the two sexes in this age group.

The Anabolic Steroid osteoporosis Relationship

Reifenstein (1957) found in European Societies that which he ascribed on account of decline of anabolic steroids about the time of the Menopause, osteoporosis in the aging women is approximately five times of that of aging men. Even taking into consideration that severe trauma among men continues to be equal to or in excess of moderate trauma until the very elderly, the incidense of fractures among the older females in Singapore is very far from being five times that of the corresponding males.

Lugg & Bowness (1957) have shown that any differences in anabolic steroid excretion (17 ketosteroid) by the male subjects of the different ethnic groups (including Europeans) of Singapore could be regarded as reflections of differences in weight. In the light of this evidence therefore it would not be unreasonable to assume that the anabolic steroid osteoporosis relationships of the local aging females are also analogous one with the other and with that of the European females as well. Is then the local female fracture pattern another example of the lack of correspondence between osteoporosis incidence and fracture incidence? It may be that the local anabolic steroid osteporosis relationship is different (unlikely) and that the local fracture pattern is an expression of this difference.

The Role of Diet

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EPIDEMIOLOGY OF FRACTURES OF THE FOREARM AMONG THE MAJOR RACIAL GROUPS IN SINGAPORE

2 *Incidences Compared (A Preliminary Study)*

By

P C N Wong

INTRODUCTION

In a previous paper Epidemiology of the Fractures of the forearm in a Mixed South East Asian Community Singapore the material was discussed as that arising from the population as a whole

It is the object of the present study to use the same material but to break it up into the three major racial groups Chinese Malays and Indians (including the Ceylonese) and compare the fracture patterns deduced one with the other and with that of a European Community (Malmo Sweden)

It is to be emphasized that this is a preliminary survey only and the study will be extended when more data become available

THE POPULATION AT RISK

The Singapore Community of 1 445 929 persons is made up of Chinese 75 per cent Malays 14 per cent Indians and Ceylonese 9 per cent and 2 per cent of Eurasians and Europeans That part of the 1957 census (which is the one used in the present study) showing the population by Race sex and 20 year age groups is shown in Table 1 The small community of Eurasians and Europeans have produced only a small number of forearm fractures during the 1962 63 period and are not included in the material under analysis

MATERIAL

There are 1699 forearm fractures and for convenience of description they are subdivided thus

1 Fractures of the distal radius or ulna or both (defined as fractures within 3 cms of the radio carpal joint) There are 9[illegible]6 cases

2 Fractures of the shafts of the radius or ulna or both (618 cases)

3 Fractures of the proximal radius i e head and neck (41 cases)

4 Fractures of the Olecranon (42 cases)

These fractures according to Race sex and 20 year age groups are shown in Tables 2 3 4 and 5

TABLE 1

Singapore Population by Race Sex and Twenty Year Age Groups in 1957

Age group (in thousand)	Malay		Chinese		Indian	
	M	F	M	F	M	F
0 – 19	53.1	53.4	303.4	281.4	26.6	23.1
20 – 39	35.3	28.7	138.0	139.8	37.8	11.6
40 – 59	12.4	9.3	94.8	86.5	19.9	2.9
> 60	2.5	2.4	19.5	[illegible]	1.7	0.5

TABLE 2

Fractures of the Distal End of Forearm in Singapore 196[illegible]–1963

Age group	Malay		Chinese		Indian	
	M	F	M	F	M	F
0 – 19	91	10	258	49	84	25
20 – 39	21	3	102	20	29	9
40 – 59	15	9	52	63	48	11
> 60	4	4	33	43	9	5
Total	131	26	44[illegible]	175	170	50

TABLE 3

Fractures of the Shaft of the Radius or Ulna or Both in Singapore 19[illegible]–1963

Age group	Malay		Chinese		Indian	
	M	F	M	F	M	F
0 – 19	97	30	200	37	80	30
20 – 39	11		49	[illegible]	12	4
40 – 59	3	0	19	6	15	1
> 60	1	0	11	4	1	0
Total	112	32	279	54	108	35

Definitions (after *Alffram* & *Bauer* 1962)

Children (boys and girls) are defined as being from 0 year to 19 years young adults 20-39 middle age 40-59 and old age as from 60 years upward

Age Specific Rate Age specific rates are calculated from the population figures

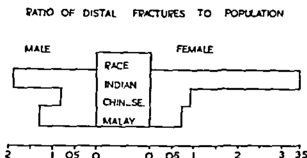


Fig. 1

Ratio of percentage of distal forearm fractures divided by the population percentage of each sex of each race in Singapore.

(Table 1) as the annual incidence of fractures per 10,000 males or females in each 20 year age group.

The racial composition of the polyglot population of Malaya (and this applies equally well to Singapore) excluding Europeans and Eurasians, consists of (*Del Tufo* 1949):

1. Malays: racial composition predominantly *Mongoloid*.
2. Chinese: racial composition, essentially *Mongoloid*.
3. Indians: racial composition *Caucasoid-Carpentarian*.

RESULTS FROM THE SURVEY

Distal Fractures

There are 997 distal forearm fractures of which 157 or 15·7 per cent of the total are Malays: 131 or 83·4 per cent are males and 26 or 16·6 per cent are females.

The Indians contribute 220 or 22·1 per cent: 170 or 77·3 per cent are males and 50 or 22·7 per cent are women. The Chinese make up the remainder which is 620 or 62·2 per cent of the total. The males of the latter number 445 or 71·8 per cent and the females 175 or 28·2 per cent.

The racial groups expressed as a percentage of the total population and the percentage of fractures contributed by each are shown in Table 6 and the ratio of percentage of fractures divided by population percentage of each sex of each racial group is graphically represented by Fig. 1. In relation to the size of its population the contribution of fractures by both the Indian Males and Females is considerable.

Males (Fig. 2)

In all age groups Indian males have the highest incidences and among the boys and young adults they are followed by the Malays and

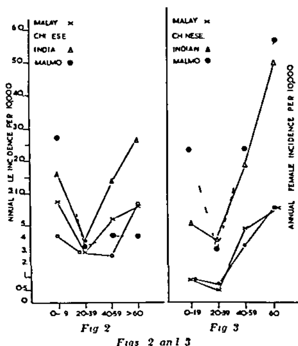


Fig 2   *Fig 3*

Figs 2 and 3

Annual male and female incidences of fracture of the distal forearm per 10 000 of population according to age among the major races in Singapore

then the Chinese but in middle age the Malay incidence exceeds the Chinese and in old age Malay and Chinese incidences approximate For the Chinese the lowest incidence occurs in the 40–59 groups where as among the Indians and Malays this occurs among the young adults

Compared with Malmo the rates for the local boys are considerably lower Among young adults Chinese Malay Indian and Malmo rates correspond reasonably closely In middle age the order is Indian Malay Malmo with the Chinese least of all All the local incidences exceed that of the Swedish Community in old age

Females (Fig 3)

Malay and Chinese females have incidences which correspond very closely in all the four age groups Their girls and young female adults have rates which are below their boys and young male adults but in middle age and the aged male and female incidences are almost identical

Indian female rates are the highest for the three Races in all the age

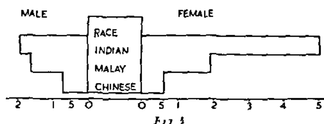


Fig 4

Ratio of percentage of shaft fractures divided by the population percentage of each sex of each race in Singapore

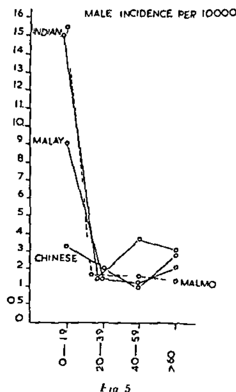


Fig 5

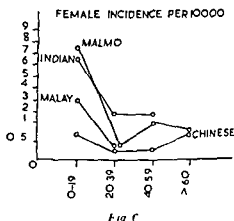


Fig 6

Figs 5 and 6

Annual male and female shaft fractures per 10 000 of population according to age among the major races in Singapore

groups They exceed their males in middle and old age and correspond fairly well with those of the Swedish females in all except the girls

Both the Chinese and Malay female rates are considerably below those of the Indian and Swedish females

TABLE 4

Fractures of the Proximal Radius in Singapore 1962–1963

Age group	Malay		Chinese		Indian	
	M	F	M	F	M	F
0 – 19	0	4	11	2	2	3
20 – 39	2	0	5	1	4	2
40 – 59	0	0	2	1	1	1
> 60	0	0	0	0	0	0
Total	2	4	18	4	7	6

TABLE 5

Fractures of the Olecranon in Singapore 1962–1963

Age group	Malay		Chinese		Indian	
	M	F	M	F	M	F
0 – 19	4	0	18	2	4	2
20 – 39	1	0	0	0	1	0
40 – 59	0	0	2	2	1	0
> 60	0	0	2	2	1	0
Total	5	0	22	6	7	2

TABLE 6

	Percentage of population		Percentage of fractures	
	M	F	M	F
Chinese	74.5	80.2	59.8	70.0
Malays	13.9	14.1	17.5	10.4
Indians	11.6	5.7	22.7	19.6

Evidence from the present survey suggests the existence of three fracture patterns for the distal forearm in Singapore. Among the females the Malay and Chinese patterns resemble one another very closely whilst the Indian one bears close analogy with that of Malmo. There is not the same agreement among the various male patterns as there is among the females.

Shaft Fractures

There are 620 fractures of the shaft of the forearm bones. The Malays total 144 or 23.2 per cent of the total, 112 or 77.7 are men and 32 or

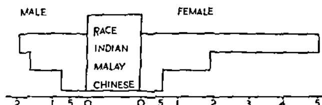


Fig 4

Ratio of percentage of shaft fractures divided by the population percentage of each sex of each race in Singapore

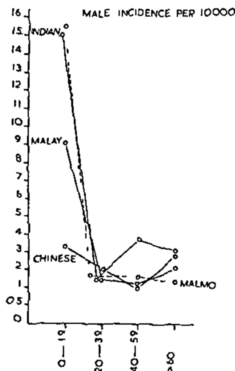


Fig 5

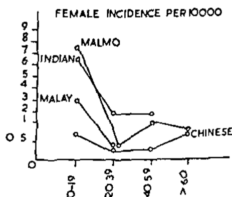


Fig 6

Figs 5 and 6

Annual male and female shaft fractures per 10 000 of population according to age among the major races in Singapore

groups They exceed their males in middle and old age and correspond fairly well with those of the Swedish females in all except the girls

Both the Chinese and Malay female rates are considerably *below those* of the Indian and Swedish females

Of the three Races the Indian cancellous fracture pattern tends more to the European than the other two Their female rates in middle and old age exceed those of their male and correspond fairly closely with those of Malmo

They also show the dramatic and sharp rise in these age groups characteristic of a European Society—undeniable evidence of progressive fragility of cancellous bone with increase in age Some evidence of this latter process is found among the Chinese and Malay females but it is hardly comparable to that occurring among the European and Indian females

Of the local males only the Indians give clear cut evidence of increasing cancellous fragility with age The Malays and Chinese Males like those of their females and males of Malmo give also only little evidence of such a progressive degenerative process

There is very little evidence of increasing fragility in cortical bone with age in either sex of all the races

It is tentatively believed that the differences or similarity of fracture patterns (cancellous bone) for each of the local races is merely an expression of the differences or similarity of racial composition This was pointed out in the earlier investigation which dealt with the local population as a whole

The question now arises—are the patterns deduced for each of the major racial group characteristic of that particular race? And as was also pointed out previously this can only be known if epidemiological surveys are conducted upon similar races whether they may be Malay Chinese or Indian living elsewhere under similar more adverse or better environmental conditions (most important of which is diet)

The present findings add no evidence to any hypothesis that explains increasing cancellous fragility as a result of osteoporosis which *Reifenstein* (1957) has found to accompany the decline of anabolic steroids in aging females

There is evidence to indicate that diet in Malaysia and Singapore is below that of European Communities in Calories proteins and calcium (*May & Jarcho* 1961 Household Budget Survey Federation of Malaya 1957 58)

In terms of proteins the Chinese are the best fed followed by the Malays then the Indians and in terms of calcium the order is Indian Chinese then Malay but both are below recommended values In all the Races the females fare the worse (*Llewellyn Jones* 1962)

If dietary considerations were all important in fracture aetiology

why are the Chinese and Malay female incidences so far below and the Indian female incidences merely comparable with those of a European community? Why is there so close a correspondence between male and female rates among the Chinese and Malays in the older age groups? *In Singapore there is thus a considerable lack of correspondence between fracture incidence and the dietary intake of the population* This gives considerable support to *Bauer's* opinion that dietary considerations are unimportant in fractures in the aged

Yet inspite of strong evidence to the contrary in the present study it is still difficult to imagine dietary considerations being anything else other than extremely important factors in fracture aetiology It may still be that this lack of correspondence between diet and fracture incidence is apparent rather than real This of course can only be proved or otherwise when races similar to those of the local population living elsewhere are studied with regard to fracture patterns under varying conditions of diet

CONCLUSIONS AND SUMMARY

The present survey has deduced

1 That in Singapore distinct fracture patterns for cancellous bone exist for the different ethnic groups and that similar races produce similar fracture patterns

2 That among the Indians in both sexes there is undoubted evidence of increased cancellous fragility with increase in age but in both sexes among Chinese and Malays there appears only a little increase in this degenerative process with similar age advances

3 That the fracture patterns for cortical bone are less distinct This is probably due to the fact that cortical bone shows little tendency to degenerate with age

4 That there is a lack of correspondence between osteoporosis incidence (*due to decline of anabolic steroids in ageing females*) and fracture incidence

5 That there is a lack of correspondence between dietary intake and fracture incidence This however may still be apparent rather than real

It is again emphasized that when further data become available the present survey will be extended

RESUME

Il ressort de la presente etude

1 qu il existe a Singapour des modeles distincts de fractures des os spongieux chez les differents groupes ethniques et que les races similaires produisent des modèles de fractures similaires

2 que parmi les Indiens des deux sexes il y a une evidence indiscutable d une fragilite accrue des tissus osseux spongieux avec l age alors que dans les deux sexes cheq les Chinois et les Malais il n y a qu une legere augmentation du processus dégeneratif aux ages avances correspondants

3 que les modeles de fractures pour les os compacts sont moins distincts Cela est probablement du au fait que l os compact ne montre qu une petite tendance a la degeneration avec l age

4 qu il existete un manque de correlation entre l incidence de l osteoporose (due a la diminution des *steroides anaboliques chez les* femmes agees) et celle de la fracture

5 quil un manque de correlation entre le regime dietetique et l incidence de la fracture Cela peut toutefios etre plus apparent que reel

Il est souligne que la presente etude sera completee lorsque des donnees ulterieures pourront etre obtenues

ZUSAMMENFASSUNG

Aus der vorliegenden Ubersicht schliesst man

1 Dass in Singapore bestimmte Bruchformen des Markknochen in den verschiedenen Volksgruppen auftreten und dass ahnliche Rassen ahnliche Bruchformen aufweisen

2 Dass bei den Indern beiderlei Geschlechts mit zunehmenden Alter *zweifellos eine zunehmende Gebrechlichkeit der Markknochen vor*handen ist Bei den Chinesen und Malayen scheint jedoch nur eine geringe Zunahme dieses degenerativen Prozesses mit einer entsprechenden Alterszunahme aufzutreten

3 Dass die Bruchformen von Rohrenknochen weniger verschieden sind Dies ist wahrscheinlich auf die Tatsache zurückzufuhren dass Rohrenknochen nur eine geringe Neigung zur Altesdegeneration haben

4 Ein Mangel von Ubereinstimmung zwischen dem Vorkommen von Osteoporosis (wegen der Abnahme von anabolischen Steroiden bei alternden Frauen) und dem Entstehen von Brüchen ist vorhanden

5 Dass ebenfalls ein Mangel von Ubereinstimmung zwischen Er

n'ihrung und dem Auftreten von Bruchen zu beobachten ist Dies ist jedoch moglicherweise nur scheinbar und nicht wirklich

Es wird wiederum hervorgehoben dass die gegenwärtige Untersuchung ausgeweitet werden wird sobald weitere Daten erhalten werden

ACKNOWLEDGEMENT

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THE LATERAL STABILITY OF THE KNEE JOINT

By

L G Hallén and O Lindahl

Opinions are divided on the manner in which the lateral stability of the knee joint should be examined and on the implications of any lateral instability found We have studied this problem in the clinic and on autopsy specimens and our findings are reported in this article

PREVIOUS STUDIES

Chapchal (9) the author of the only monograph on methods of orthopaedic examination stated in 1954 that in an examination for any lateral instability the knee joint should be fully extended Lateral instability was ascribed to damage to the collateral ligaments and said to be proportional to the severity of the injury Similar opinions have been expressed in a number of the major text books on orthopaedics (2 3 10 19 23 24) in monographs on the knee joint (5 21) and articles in journals (13 16) There is thus a general view in the orthopaedic and surgical literature that the injuries to the collateral ligaments should be examined with the knee fully extended and that any instability in this position is a sign of damage primarily to the tibial collateral ligament

A different view has been expressed by some authors namely that the knee is stable in extension even if the tibial collateral ligament is severed but as *Palmer* (17 18) writes "If the instability continues in hyperextension this must be interpreted as a sign of insufficient tension of the crucial ligaments *De Palma* (11 12) too asserts that lateral instability of the knee in extension can be present only if damage to the tibial collateral ligament is associated with injury to the anterior cruciate ligament This opinion is shared by *Brantigan & Voshell* (6) *Böhler* (7) *Casagrande & Frost* (8) *Hult* (12) and *Smith* (22)

Abbott et al (1) who examined 6 knee-joints in connection with the

division of various ligaments gives an apparently contradictory account of his findings relating to lateral instability. First it is stated that no lateral instability was obtained even when both the tibial collateral ligament and the anterior cruciate ligament were divided and then that lateral instability in hyperextension when present was due to division of both the tibial collateral and the anterior cruciate ligaments. A similar contradictory view is expressed by *Bohn & Lyck* (4) on the basis of experiments on 4 knee joints. They assert that it is impossible to obtain lateral instability in extension even when the medial collateral and anterior cruciate ligaments are divided but in the discussion they say that if there is such lateral instability it is likely that both these ligaments are ruptured. *Saugmann Jensen* (20) states on the basis of tests on a single knee specimen that true lateral instability is obtained only when the tibial collateral and anterior cruciate ligaments and the *posterior capsule have been divided but that a moderate instability is* obtained in extension when only the two ligaments have been divided.

Thus three contradictory views can be distinguished in the literature as regards the importance of the tibial collateral ligaments to lateral instability.

(1) Lateral instability is due to rupture of the tibial collateral ligament and the examination must be made in extension. This is probably the method now most commonly taught to students and specialists alike.

(2) Lateral instability in extension is due to rupture of both the tibial collateral and the anterior cruciate ligaments.

(3) There is generally no lateral instability in extension when the tibial collateral and cruciate ligaments are divided but if such instability in this position should be found these injuries can be assumed to be present.

NOMENCLATURE

The terminology in the literature referred to is varied and obscure. The knee joint is commonly taken to be extended at an angle of 180°. This position is referred to variously as full extension, extension, mid position, etc. Further extension is referred to as maximum extension and hyperextension but sometimes extension or full extension. There is usually no indication of which position is intended and this is probably one reason why statements in the literature are controversial.

It would seem logical from the functional standpoint that the knee should be considered extended when there is resistance to further extension whether this occurs at an angle between the thigh and lower

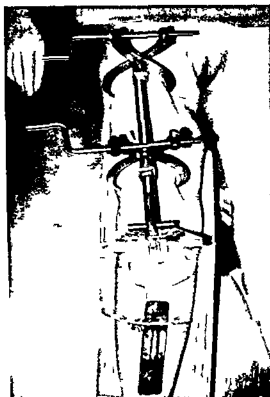


Fig 1
Apparatus for measuring the lateral mobility and rotation of the knee joint

leg of 180 185 or 190 The axes of these more or less curved bones surrounded by soft tissues of widely varying form can be difficult both to define and to measure In the following the term ***extension*** denotes the position in which the knee is extended to the point where there is resistance to further extension

MATERIAL

The study was performed on 16 knee joints from autopsy cases and on some 50 knee joints of out and in patients The age and sex distributions for the autopsy cases were as follows

Age	< 40	40 60	> 60
Men		4	3
Women	1	2	6

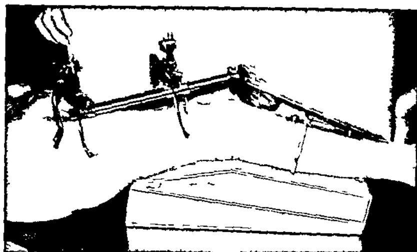


Fig 2

Apparatus for measuring the lateral mobility and rotation of the knee joint The joint is held in the 160 position by a special frame

METHODS

For the laboratory studies an apparatus was designed one part of which was fixed to the femur and the other to the tibia (*Fig* 1)

The lateral stability of the knee joint could be read off in degrees in any desired position of flexion

This apparatus and a uniform examination technique were developed and standardized in preliminary experiments on 5 knee joints A further 11 joints were tested systematically

After rigor mortis had been broken the lateral instability was recorded for the intact knee first in the extended position and then slightly flexed with an angle of about 160 (*Fig* 2) The superficial and deeper portions of the tibial collateral ligament and the anterior and posterior cruciate ligaments were divided in turn After each division the lateral stability was tested in the two positions For two joints the lateral instability was also tested after the posterior capsule with its ligaments had been divided In the tests one examiner supported the thigh fixation device and took the readings while the other manipulated the lower leg with as far as possible equal force in the different experiments and without seeing the scale In spite of this fairly standardized technique it proved difficult to obtain accurately reproducible values This was because of the elasticity of the tissue and the difficulty in applying a constant force to the knee Owing to difficulty in determining accurately or defining the mean or neutral position the lateral instability was not divided into abduction and adduction

For the examination of the patients the usual clinical and radiographic methods were used In the tests of lateral instability the patient s foot was held by the examiner between the elbow and trunk so



Fig 3
The grip for examining the lateral mobility of the knee joint

that both hands were free to hold the knee in the required flexed position while moving the knee in ab- and adduction (Fig 3)

RESULTS

Irrespective of whether the knee was intact or the ligaments were divided none of the 55 tests (5 tests on each of 11 cases) on autopsy specimens displayed lateral instability in extension Sometimes however there was a swing of a few degrees on the scale if a large force was applied but this was the same for intact knees and when all the ligaments had been severed Only when the posterior capsule had been divided as well as the tibial collateral and cruciate ligaments was the stability of the joint impaired and then to such an extent that it could be moved freely in any direction For intact knee joints the average lateral instability in the 160° position—that is with the knee flexed 20°—was 9° with a range of 8–13° (Table 1) When the superficial portion of the tibial collateral ligament was severed the lateral instability increased to an average of 13° and on division also of the deep portion it was increased to 1[illegible] The division then of the anterior cruciate ligament gave a lateral instability of 18° and when the posterior cruciate was divided the total lateral instability on an average was 21° Thus the lateral instability increased a few degrees as each of the ligaments was divided

TABLE 1

Lateral Mobility (in Degrees) of 11 Knee Joints in the 160° Position after Division of the Ligaments in Turn. The Figures in Parentheses Denote the Increase Relative to the Value for the Intact Knee

Intact knee		Mobility on division in turn of			
		Tibial coll. lig.		Cruciate lig.	
		Superfic.	Deep	Ant.	Post.
	10	14 (4)	17 (7)	21 (11)	24 (14)
	9	12 (3)	14 (5)	16 (7)	20 (11)
	9	11 (2)	11 (2)	13 (4)	18 (9)
	13	14 (1)	17 (4)	19 (6)	20 (7)
	8	13 (5)	20 (12)	25 (17)	25 (17)
	9	14 (5)	17 (8)	21 (12)	26 (18)
	9	14 (5)	18 (9)	20 (11)	27 (18)
	8	12 (4)	16 (8)	17 (9)	19 (11)
	9	13 (4)	12 (3)	16 (7)	15 (6)
	8	9 (1)	9 (1)	12 (4)	19 (11)
	12	13 (1)	16 (4)	17 (5)	18 (6)
Mean	9	13 (4)	15 (6)	18 (9)	21 (12)
Range	8–13	9–14	9–20	12–25	15–27

Concurrently to this study special attention was given to the clinical cases of knee disorders due either to injury or osteoarthritis. A number of cases of damage to the tibial collateral ligaments were diagnosed in which there was a definitely greater lateral instability than on the healthy side when tested in slight flexion; in extension, however, all these knees were stable. At the same time 7 cases with a marked instability in extension were examined. 2 of these were cases of femoral condyle fracture. In one of them the femoral condyle was found at autopsy to be displaceable one centimetre and this resulted in an instability of 20° in extension. In 2 cases the movement was due to recent fracture of the tibial condyle (Fig. 4) and in 3 cases to severe osteoarthritis with destruction of one of the tibial condyles (Figs. 5–7). In a further case with similar lateral instability after an acute abduction trauma there was no radiologic evidence of a fracture; surgical exposure of the tibial collateral ligament and condyles disclosed an intact ligament but a definite depression of the lateral tibial condyle.

In all the clinical cases of instability in extension there was thus a loss of substance in the condyles.



Fig 4

Radiographs of the knee joint in a compression fracture in the medial condyle of the tibia The mobility of the knee joint in extension is represented in the two radiographs

THE MECHANICS OF LATERAL INSTABILITY

In extension of the knee the four condyles are pressed against one another with a force that is proportional to that with which the knee is extended (Fig 8) The force is transmitted to the condyles as in a pair of nut crackers through the resistance presented by the posterior capsule (Fig 8 a) This capsule strong in itself is reinforced by a number of smaller ligaments and tendons and offers a firm resistance to over extension So long as the joint is extended and thus the posterior capsule is tense it is mechanically impossible to bend the knee laterally irrespective of whether there are stabilizing structures at the sides or in the middle of the joint (Fig 8 b) So long as the force extending the knee exceeds that tending to cause a lateral movement the 4 condyles will be pressed together

Fig. 5

Radiographs of the knee joint in a severe case of osteoarthritis and loss of substance in the medial condyles of the femur and tibia. The mobility of the knee in extension is represented in the two radiographs.

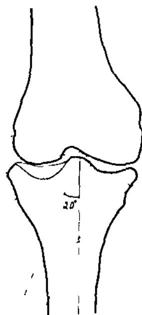


Fig. 6

Tracing of radiographs of the knee joint with a lateral mobility of 20° in extension owing to severe osteoarthritis and loss of substance in the medial condyles of the femur and tibia. The dotted line indicates the position of the knee joint on adduction in extension.



Fig 7

Knee joint with marked lateral mobility in extension The radiograph shows osteo arthritis and loss of substance in the lateral condyles of the femur and tibia

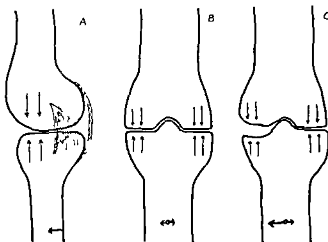


Fig 8

A The knee joint in extension The condyles are pressed together when the posterior capsule is stretched

B In extension with the condyles pressed together the knee is stable in the lateral direction

C When there is a loss of substance in the condyles there may be lateral mobility in extension This is not prevented by intact ligaments

Hence so long as the two condyles on each side of the knee joint are in contact there can be no lateral movement in the extended position If any of the condyles is subjected to loss of substance these mechanical conditions are disturbed and even in extension two positions of equilibrium are obtained between which movement can take place (Fig 8 c)

DISCUSSION

In this study we have found that lateral instability in extension is typical of cases in which there is a loss of substance in the condyles of the knee-joint but not a symptom of damage to the ligaments. This is supported by the analysis of the purely mechanical conditions for lateral instability. That this situation has not been demonstrated previously may be ascribed to the fact that in cases of acute injury lateral mobility is sometimes found in extension because of damage to the posterior capsule and compression fractures of the condyles which have not been found on radiographic examination; this occurred in one of our cases. This difficulty of diagnosing fractures of the knee condyles by radiography has been pointed out by *Hirsch* (14) in a paper on experimental knee fractures.

How then shall injuries, especially those of the tibial collateral ligament, be diagnosed? The examination must be performed in the flexed position. In flexion of only a few degrees the posterior capsule can prevent marked lateral mobility. A flexion of 20° will relax the capsule enough to permit a considerable lateral mobility and in this position the full range of lateral mobility permitted by severed collateral and cruciate ligaments will be obtained. If, on the other hand, the flexion is greater than this it will be increasingly difficult to restrict the movement to lateral mobility and simultaneous rotation of the hip joint will easily result; this will complicate the assessment of the lateral instability.

With an angle of 160° there was an increase in lateral mobility as the two portions of the tibial collateral ligament and the cruciate ligaments were severed in turn but this increase was strikingly moderate and in spite of the fact that the two portions of the tibial collateral ligament and both cruciate ligaments were severed, the lateral mobility was sometimes as small as 6°. An examination of the damaged knee alone will therefore hardly suffice to show whether the lateral instability is normal or pathologic. To confirm the diagnosis a careful comparison between the two knees and experience in such an examination are necessary. The technique shown in Fig. 2 would seem to give the best results. The severance of both portions of the medial collateral ligament may sometimes result in such a small increase in lateral mobility that (compared with the sound side) it will hardly be detectable at a clinical examination. A study of the rotational stability of the knee joint, to be published in due course, will show that by examining the rotation of the

joint one can obtain a more accurate measure of the extent of damage to the two portions of the tibial collateral and the anterior cruciate ligaments

SUMMARY

A clinical examination of some 50 knee joints in patients and an experimental study of 16 knee joints from autopsy specimens has been performed The relationship between the lateral instability of the knee joint and various injuries to the ligaments was especially investigated It was concluded that lateral instability of the knee joint in extension must be due to a loss of substance in the condyles of the knee owing to fracture or osteoarthritis and that in other cases the knee in full extension is always stable in the lateral direction irrespective of how many of the ligaments are severed This stability is due to the posterior articular capsule which in extension presses the 4 condyles together and prevents any lateral mobility so long as extension is maintained

In severe injuries in which the posterior capsule is also ruptured the knee becomes completely unstable

The method commonly recommended for testing the ligaments of the knee joint in extension is inaccurate

RESUME

Un examen clinique de 50 articulations du genou de malades et une etude experimentale de 16 articulations de genou provenant d autopsies ont ete accomplies Les rapports entre l instabilite laterale de l articulation du genou et differentes lesions des ligaments ont ete specialement etudies Il est conclu que l instabilité laterale de l articulation du genou en extension doit etre due a une perte de substance des condyles du genou provoquee par la fracture ou l ostéoarthrite et que dans les autres cas le genou en pleine extension est toujours stable en direction laterale quel que soit le nombre des ligaments blessés Cette stabilite est due a la capsule articulaire posterieure qui en position d extension presse ensemble les quatre condyles et empeche toute mobilité laterale aussi longtemps que l extension est maintenue

Dans les lesions graves chez lesquelles il y a egalement rupture de la capsule posterieure le genou devient entierement instable

La méthode recommandee communément pour mettre a l epreuve les ligaments de l articulation du genou en extension ne fournit pas des données exactes

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OPERATIVE TREATMENT OF NON UNITED FRACTURES OF LONG BONES

By

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Several operative methods are in use for the treatment of established non union of diaphyseal fractures of the long bones The incidence of successful results as well as the duration of post operative immobilization until safe healing occurs vary considerably in the different reports this depending mainly on the operative method used by each author Autogenous or homogenous bone transplants are commonly used as inlay onlay or sliding grafts with or without resection of the sclerotic bone ends and with or without internal fixation Thick compact bone transplants are usually preferred by several surgeons as securing good stabilizing as well as biological properties for the healing of the non union

An operative method for treatment of non united fractures of the long bones is described in the present communication The method is based on the following principles

a) the fibrous and the sclerotic bone tissue at the site of the non union are resected only partially

b) the bone fragments are not dislocated and the fibrous connections around the non union stabilizing the bone ends are preserved as advocated by *Phemister* (1947)

c) the obliterated medullary cavity is carefully opened and its continuity restored

d) a block graft of cancellous iliac bone together with additional bone chips are used as transplantation material and

e) internal fixation is used only in cases with pronounced instability of the bone fragments

A series of non united of diaphyseal fractures have been treated by this method and the obtained results are reported herewith



Fig 1
The longitudinal trench has been chiselled bridging over the space of the non union A part of the fibrous tissue intervening between the bone fragments and the sclerotic bone obliterating the marrow cavity have been removed through the trench



Fig 2
The graft

THE OPERATION

Through a suitable skin incision and dissection of the soft tissues the periosteum is freed and opened longitudinally Care is taken to preserve its continuity as much as possible The non union is exposed subperiosteally A longitudinal trench approximately 1 cm wide and [illegible] 7 cm long bridging over the space of the non union is chiselled into the cortical bone Through the trench only a part of the fibrous tissue intervening between the bone fragments is excised The remainder

The average age of the patients was 49 5 years the sex distribution 18 men and 5 women and the average time between the occurrence of the fracture and the operation for the non union by the present method was 27 months The distribution of the material is demonstrated in Table 1 An established non union was in every case diagnosed by clinical and X ray examination Case no 17 concerned however a delayed rather than non union of a 4 months old fracture of the tibia In another case (no 18) a real pseudarthrosis had developed at the time of the operation after an old fracture of the humerus This case is reported in detail below

There was no case of severe dislocation of the bone fragments in this material However in one case (no 24) a 7 cm long defect of the tibia was present

In five cases (no 4 10 15 23 and 24) the primary fracture had been complicated by infection but there were no signs of active infection at least six months before the operation for the non union was performed

RESULTS

In nineteen out of the 25 non unions operated upon by this method healing occurred primarily after a postoperative immobilization of the extremity with a plaster cast for an average time of 3 25 months The operation failed to secure healing of the non union in altogether 6 cases A postoperative infection developed in 3 previously infected non unions (cases no 10 23 and 24) In case no 24 a below knee amputation was *performed later The other two patients refused a new operation* and they are using a splint at present time

Three more cases which failed to heal by the operation are described below

Case no 18 concerned a humerus fracture treated primarily conservatively which developed a non union The patient was operated upon in another hospital for his non union twice without success At the admission in the department there was a severe pseudarthrosis of the humerus with an abnormal motion of more than 45 at every direction At operation the hypermobile bone fragments were stabilized by help of a plate and screws and the non union itself was treated as described above However because of postoperative signs of a partial lesion of the radial nerve a revision of the operation area was performed two months later The [illegible] of the non union was examined at that occasion too and since there were [illegible] clinical and X ray signs of consolidation the screws and the plate were removed A slight motion could however be identified at the site of the non union after removal of the plate and a new grafting was performed in the same way as previously but without internal fixation After 5½ months of immobilization in plaster there were no sure X ray signs of healing but the plaster cast was removed by an other surgeon and a leather splint was applied instead A severe pseudarthrosis developed soon again The patient is now using a splint as he refused a new operation

The second case (no 20) concerned an open fracture of the tibia which was operated upon primarily elsewhere A non union developed for which the patient was operated upon 5 times without success before he was admitted to the depart

ment The non union was again operated upon by the method used in this series without internal fixation After 4 6 months of immobilization by plaster there were X ray signs of periosteal callus formation around the non union but no sure signs of healing The plaster was then removed by another surgeon and the patient was supplied with a leather splint A new non union developed soon for which the patient was operated upon by the same surgeon A sliding graft was used this time and after another 6 months of immobilization in plaster a sound healing of the non union occurred finally

The last case (no 91) concerned a patient with a fracture of both ulna and radius which was treated primarily conservatively in another hospital Because of a developed non union the patient was operated upon twice before admission in the department The non union was then operated upon according to the described principles without internal fixation After 5 months of immobilization in a plaster cast the case was considered as a delayed union by another surgeon and a reoperation was done using internal fixation with plates and screws and bone grafting After 4 months of immobilization in plaster the fractures were considered healed The plates and the screws were removed 11 months later but after another 4 weeks a spontaneous refracturing of both the bones occurred X ray examination showed signs of a non union within both ulna and radius and at the same place as before A new bone grafting operation according to the present method combined with internal fixation of both the bones by help of plates and screws was performed Finally a good healing was secured after $5\frac{1}{2}$ months of immobilization in a plaster cast

The failure in healing of the non union by the described method in the reported series is ascribed to post operative complication viz infection in 3 cases Inadequate post operative immobilization was apparent as the cause of failure in the other three cases

DISCUSSION

There are certain biological principles for the management of non united fractures which although well known are often neglected by many surgeons in the operative treatment of such cases These principles may be summarized as follows (i) Resection of the fibrinoid tissue filling the gap of the non union (ii) Restoration of the continuity of the obliterated marrow cavity (iii) Stimulation of the osteogenesis (iv) Sufficient immobilization of the bone fragments and (v) avoidance of extensive damage and necrosis of bone and tissues

According to *Crist Mc el & McLean* (1954) in established non unions the resection of the fibrinoid tissue filling the space between the bone fragments is an important procedure Fibrinoid tissue acts in this case as a barrier to the osteogenetic elements arising from the periosteum



Fig. 4

Case No. 5. a) Established non union of the tibia. b) X-ray taken immediately after the operation. Note the cancellous transplant lying in the trench. c) $4\frac{1}{2}$ months later. Complete healing of the non union by fusiform bone callus.

and the endosteum preventing them from traversing the fracture interval and securing the consolidation of the bone fragments by the development of bone callus. The authors found that even if the resection of the fibrinoid tissue is not necessary in cases of delayed union, this is of definite importance in the operative treatment of established non union.

The restoration of the continuity of the obliterated marrow cavity is important in the treatment of a non union. The sclerotic bone blocking the cavity in the vicinity of the non union acts also as a barrier preventing the endosteal elements from displaying their osteogenetic activity. Removing of the sclerotic bone provides sufficient blood supply and allows the endosteal osteoblasts and the undifferentiated marrow cells to contribute to the healing of the non union. It is known that the periosteal external callus is usually more pronounced than the endosteal internal callus. However, in some bones and under certain circumstances

the internal callus may be of greater importance for the healing of a fracture than the external (*Ham & Harris* 1956)

Bone transplantation for the stimulation of the healing of non united fractures has been applied to an increasing extent during the last decades Many experimental works concerning bone transplantation have been published and are reviewed in an article by *Chase & Herndon* (1955) However the majority of the authors report that fresh autogenous bone is superior to any other type of bone transplant (*Siffert* 1955 *Bonfiglio* 1958 and others) Transplanted compact bone either autogenous or homogenous dies is absorbed and replaced slowly by new bone provided by a proliferative reaction of the osteogenetic elements of the host (*Urist et al* 1954) The transplant is used by the host as a framework for the building of the new bone furthermore osteogenesis may be stimulated in these cases by an inductive process (*Urist & McLean* 1952) Cancellous autogenous bone grafts have been proved by experimental and clinical studies to be superior to compact autogenous bone transplants (*Dick* 1946 *Higgs* 1946 *Abbot et al* 1947 *Merle d Aubigne* 1949 *Campbell et al* 1953 *Siffert* 1955 and others) In this case some endosteal osteogenic cells of the cancellous chips do survive transplantation and give rise to new bone formation (*Ham & Harris* 1956) Furthermore the transplant because of its architectural structure presents more abundant possibilities for blood vessels and granulation tissue to intrude upon it The graft is thus absorbed soon and new bone formation occurs in a considerably shorter time than with compact bone

Immobilization of the bone fragments has a quite different aspect in the treatment of fresh fractures than in that of a non union In the former case an internal fixation might be in certain cases necessary to keep unstable fragments in contact with each other during the healing of the fracture However in non union risk of displacement of the fragments hardly exists The scar tissue around the bone fragments is sufficient to secure immobilization Any kind of internal fixation is therefore usually unnecessary in such cases (*Phemister* 1947) A well *fitting plaster is usually sufficient to give an appropriate immobilization* of the fragments

Studies of the physiopathology of fracture healing have shown that the regenerative processes do not start before damaged bone and tissues are absorbed at the site of fracture (*Urist et al* 1954) Therefore an important principle in the treatment of non unions is to avoid as much as possible interventions which because of their character or

extent result in excessive damage to the tissues The use of electric saws or drills results in necrosis of the bone The insertion of metals has also been found in recent studies (*Finneus* 1956 57) to cause a pathologic reaction of the bone Such factors as these retard fracture healing

The results obtained by different authors in the treatment of non united fractures show varying frequency of healing and time of immobilization depending on the operative method used (Table 2) Healing of a non united fracture can be obtained by any kind of operative procedure However the operative method based on the biological principles described above should give a high incidence of healing and in a shorter time [1]

TABLE 2

Cases of Non Union Treated by Different Procedures with the Incidence of Healing and the Time of Immobilization

Author	No of non unions	Percentage of healing	Time of immobilization (months)
Merle d Aubigne (1949)	1?6	81.9	4.?3
Bertelsen (1955)	270	87	
Bistrom (1955)	39	97.5	
Nyberg (1955)	81	83.9	
Amako and Coto (1955)	2?6	?6.3	
Riasenda and Perez (1956)	89	?0.0	4
Nicoll (1956)	27	100.0	3.5
Redini and Bendinelli (1959)	29	84.0	8.0
Pedroca and Bardini (1960)	12	100.0	6.7
Rivero (1960)	280	81.1	6.8

[1] Cases of non union of different localizations In certain series cases of delayed union are included Similarly infected cases and cases with severe bone defects are included in some series

In some series healing was obtained by more than one operation

[3] Cases with extensive defects are not included

SUMMARY

An operative method for the treatment of non united fractures based on certain biological principles is described Twenty five cases of diaphyseal fractures with established non union have been operated upon

[1] *Note on the proof* In a recent publication (1964) a similar technique has been used by *Williams* for the treatment of 15 cases of non union of long bones Boiled homologous cancellous bone was used as grafting material Healing was obtained in all the cases after an average immobilization in plaster of 4.5 months

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SUBASTRAGALAR TRIARTICULAR ARTHRODESIS FOR CONGENITAL CLUB FOOT IN CHILDREN AGED 2½–15 YEARS

By

RUDOLF LEMPERG

Intractable club foot in older children which seems uncorrectable by conservative treatment and operations to the soft tissues is a troublesome problem Whether early operation by triarticular arthrod sis in these patients can achieve a lasting functional and trouble-free ol is a matter for discussion

COMPOSITION OF MATERIAL

1948 t 1960 863 ca es of c ngenital club foot were treated at the Karolinska rth pae lic lini About half were primary untreated newborn ca es t were prev ou l treate l el ewhere and h d received quite inadequate The material thu l ded with an unfa urable electi n 5 3 p tients 44 patient ith 55 club f et were treated b tr rticular ro le from the age f 2½ t 15 years becau a satisfact ry p sition l not be obtain d by con ervative treatment (man pulati n plaster l braces) together with ther different operati n Of the feet treated lesi 34 had never been fully c rrected and 21 ha l had recur vu a l luctus-equin aru def rmity except one who had an -val us f ot 14 patients had al oth r c ngenit l deformities ngenital disl cations of the hip five congenit l hand contrac two mening celes with hydr cephal one cleft palate and ple deformitie Moreover apart from club f t and these ufferel f n ntal r tard ti n Hereditarily afflicted representi per ted material. Onl fi e patients onl in c uld more cases f club f ot be f und i n b ls 24 b and 20 girl Before the were u e orthopaed c hoes or braces F r the ab ence of a careful preoperative t ma be reck n d t be am ng the

Redini G & Bendinelli F Minerva ortop *10* 581 1959
Rivero S Minerva ortop *11* 219 1960
Roasenda F & Perez R F Minerva ortop 7 597 1956
Siffert R S J Bone Jt Surg *37 A* 742 1955
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Williams C J Bone Jt Surg *46 B* 398 1964

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Intractable club foot in older children which seems uncorrectable by conservative treatment and operations to the soft tissues is a troublesome problem. Whether early operation by triarticular arthrodesis in these patients can achieve a lasting functional and trouble-free foot is a matter for discussion.

COMPOSITION OF MATERIAL

From 1948 to 1960 863 cases of congenital club foot were treated at the Karolinska Institute's orthopaedic clinic. About half were primary untreated newborn cases and the rest were previously treated elsewhere and had received quite inadequate treatment. The material is thus loaded with an unfavourable selection.

Of these 863 patients, 44 patients with 55 club feet were treated by triarticular subtalar arthrodesis from the age of 2½ to 15 years because a satisfactory position of the feet could not be obtained by conservative treatment (manipulation, plaster, night splints and braces) together with other different operations. Of the feet treated by subtalar arthrodesis 34 had never been fully corrected and 21 had had recurrences. All had a cavus adductus equino-varus deformity except one who had an over-corrected plano-valgus foot. 14 patients had also other congenital deformities, among them four congenital dislocations of the hip, five congenital hand contractures and deformities, two meningocele with hydrocephalus, one cleft palate and two others with multiple deformities. Moreover, apart from club foot and these abnormalities, a number also suffered from mental retardation. Hereditarily afflicted cases are strongly under-represented in the operated material. Only five patients showed an heredity and only in one case could more cases of club foot be found among relatives. Classification by sex reveals 24 boys and 20 girls. Before the arthrodesis 34 (77 per cent) were obliged to use orthopaedic shoes or braces. For distribution with regard to age see Table 1. In the absence of a careful preoperative classification of the feet the operated patients may be reckoned to be among the so-called severe club feet.

TABLE 1

Primary Results at the End of the Postoperative Immobilization Period

Age at operation	Number of patients	Number of feet	Appearance of the foot (clinical examination)		Healing of the arthrodesis (X ray examination)		
			Good + fair	Poor	Union	Partial union	Non union
			75%	25%	6%	63%	31
2– 7 years	12	16	12	4	1	10	5
			100%	–	48%	43%	9
7–12 years	19	23	23	0	11	10	2
			88%	12%	63%	31%	16%
12–15 years	13	16	14	2	10	5	
							No X ray examination
			89%	11%	40%	45%	15%
Total	44	55	49	6	22	25	7

METHOD OF OPERATION AND AFTER CARE

All the patients reported here were operated upon by a triarticular subastragalar arthrodesis (T arthrodesis) with wedge resection of the joint surface between the calcaneum and talus the talus navicular and calcaneo cuboid Six achilles and three posterior tibialis tendon lengthenings were performed together with the bone operation Post operatively twelve cases of minor skin necrosis occurred in and one case a major skin necrosis combined with a moderate wound infection which however did not delay recovery Time of immobilization in plaster varied from 6 to 24 weeks and was in the main 12 to 14 weeks

PRIMARY RESULTS

In Table 1 is shown the primary result at the end of the period in plaster By good and fair result is meant that the foot was straight and had a satisfactory appearance Good and fair are taken together as a more careful discrimination is not possible from the information provided by the case notes By poor result is meant that the foot still showed a significant deviation from the normal position

On X ray bony bridging of the arthrodesis was seen as early as 6 weeks in one 12 year old patient but usually after 12 to 16 weeks The incidence of radiological healing by the end of the period in plaster is shown in Table 1 for the different age groups By partial union is meant here that only a part of the whole arthrodesis showed radiographic evidence of bony bridging

TABLE [illegible]

[illegible] Up of Operated Patients

Age at operation	Number of patients	Number of feet	Average [illegible] follow up	Average [illegible] follow up	[illegible]	Subjective results			Objective results			Remarks
						[illegible]	Fair	[illegible]	[illegible]	Fair	[illegible]	
2–7 years	10	14	7.1 years	[illegible] years	14 % 2	[illegible] % 5	[illegible] % [illegible]		[illegible] 3	50 % 7	[illegible] 4	(3 recurrence)
7–1[illegible] years	13	1[illegible]	9.4 year	13.[illegible] year	31[illegible] 5	5[illegible] [illegible]	19 % 3	[illegible] % 4	25 4	[illegible] % 8	[illegible] % 4	(4 recurrence)
1[illegible]–15 year	10	1[illegible]	11.3 years	[illegible].4 year	– 0	[illegible] % 3	58% 7	17 % [illegible]	[illegible] % 3	[illegible] 7	17 % 2	
Total	[illegible]	4[illegible]	9.[illegible] years	1[illegible] years	[illegible] 7	41 17	45 % 19	14 % [illegible]	24% 10	[illegible] % [illegible]2	24 % 10	

Percentages are related [illegible] the number [illegible] feet

In patients using orth[illegible] [illegible] and appliances they are related [illegible] the number of patients

FOLLOW-UP EXAMINATION

Of the 44 patients in the series 33 patients (42 feet) were followed up after 2 to 14 years, on average 9.3 years. Two patients had died, two had emigrated and the rest could not be followed up for one reason or another. Nine patients had bilateral club feet both of which had undergone triple arthrodesis, seven patients had bilateral club feet only one side undergoing operation, and seventeen patients had unilateral club foot (see Tables 2 and 3).

TABLE 3

	Number of feet	Average motion range in ankle joint	Equinus	Average foot size	Average length of lower extremity	Rigidity of 1st metatarsophalangeal joint
Bilateral club foot			77%			
bilaterally operated	18	16	14	–	–	50
Bilateral club foot			71%			
unilaterally operated	7	28	5	—1.2 cm	1.5 cm	30 %
Unilateral club feet			64.5 %			
unilaterally operated	17	21	11	—2.5 cm	1.7 cm	40
Unilateral club foot			35%			
not operated	20	48	7	– 1.9 cm	1 cm	0

The numbers are related to the operated foot

A comparison series of 20 patients with unilateral club foot selected at random who had undergone conservative treatment was also followed up. The average age of this group at follow-up was 20.4 years (range 10 to 29 years).

To assess *the subjective result* as good the foot had to be painfree in normal use but also on moderate stress. The patient had to be able to walk on uneven ground and to wear ordinary shoes, possible with insoles. The cosmetic result had to be acceptable to both patient and parents.

Satisfactory result was adjudged to have been attained when the patient had only mild trouble with his foot in the form of tiredness, difficulty in buying shoes, inability to walk trouble-free over uneven *ground and a certain stiffness in the ankle joint*, together with a less readily acceptable cosmetic result.

By poor result was meant pain in the foot on ordinary use, inability to wear conventional shoes due to foot deformities thus necessitating orthopaedic boots, and an unacceptable cosmetic result.

In *the objective assessment* of the final result consideration was taken first of the foot s function in walking then the anatomical result and the foot s appearance By good result was meant plantigrade position of the foot with good plantar thrust A slight varus position was accepted however if this was the only fault or a normal position of the foot on weight bearing with a slight adduction of the forefoot together with a satisfactory appearance

By satisfactory result was meant slight and moderate valgus or varus position of the foot on walking with poor plantar thrust of the foot slight varus position of the heel slight supination of the forefoot on weight bearing hallux rigidus diminished function of the toe extensors or moderate adduction in the forefoot and a less pleasing appearance

A poor result consisted of marked varus of the foot with a stiff gait varus position of the heel and marked supination of the forefoot painful hallux rigidus paretic toes marked adduction of the forefoot and pes plano valgus The appearance corresponded in general to the anatomical findings

On analysis of the *subjective* troubles in the operated patients certain typical complaints arose which were different for the different age groups and which did not always correspond to the objective findings First in the older patients was a feeling of stiffness in the ankle joint and trouble from the first metatarsophalangeal joint On the other hand the patients did not seem troubled by stiffness in the subtalar joints None had pain in the foot on everyday use but some had trouble with skin callouses Diminished movement of the ankle joint was a considerable complaint among the female patients in the older age group due to their subsequent inability to wear high heeled shoes In general the buying of shoes was made difficult by the fact of unequal sizes of feet and wear on shoes was very heavy The cosmetic result was more often a source of worry and even of inferiority complex in the female patients than in the males most of whom accepted it The patient s parents were usually more pleased than the patients themselves In selecting jobs most chose some kind of work where they would not be impeded by their foot deformity Many took part in sports and one was able to clear 1 90 meters in the high jump (he had barely acceptable foot form) Skating and skiing were for the majority impossible but on the other hand many could dance freely For the most part the subjective results were better than the objective except for one case of bilateral club foot in the 12-15 age group in whom the subjective result was classified as poor for cosmetic reasons while

objectively it was classified as satisfactory. The patients in the younger age groups were not so troubled by the diminished movement in the ankle and first metatarso-phalangeal joint and cosmetic considerations were of little importance in the subjective assessment. Seven out of the 33 patients (21 per cent) were still wearing orthopaedic shoes or braces as against 77 per cent before operation (see Table 2).

The *objective* results are summarized in Table 3. It can be seen that the foot and leg on the operated side are shorter than the other. The range of movement at the ankle and the incidence of equinus are also shown. In 15 feet (35 per cent) extensor function in the big toe was absent or weakened and in 24 feet (60 per cent) the same was found for the small toe extensors. All the operated cases had a more or less pronounced atrophy of the calf muscles.

TABLE 4

Comparison of the Musclefunction and Malposition in 10 Best and 10 Worst Feet Following Subtalus Arthrodsis

	Function of tibialis anterior		Function of the toe extensors		*Equinus*	Forefoot adduction	Forefoot supination	Varus of calcaneus
	Strong	Normal	Normal	Absent				
The worst feet (7 recurrences)	7	3	1	9	7	8	3	5
The best feet	4	6	7	3	7	3	0	3

To get an idea of the factors which affect the result 10 feet assessed as the worst have been compared with the 10 best (Table 4). Muscle function and deformities are compared. A powerful tibialis anterior function together with absence of toe extensor function are strongly *represented among the 10 worst feet. Peroneus function* was not assessed. The malposition most important in unfavourable results is supination of the forefoot and thereafter varus position of the heel. That equinus deformity does not affect the results more unfavourably can be explained partly by the shortening of the leg present in most cases and partly by hypermobility of the forefoot. Supination of the forefoot developed over the years after the operation in certain cases according to the patients themselves. Approximately 50 per cent had a more or less pronounced supination. 33 per cent of patients who were operated upon between 12 and 15 years of age had trouble with the first metatarso-phalangeal joint together with a flexion position of the big toe

TABLE 5

Consolidation of the Arthrodesis at the Follow-Up X-Ray Study

Age at operation	Number of patients	Number of feet	Consolidation in the talocalcaneal joint			Talonavicular consolidation			Calcaneocuboid consolidation			Consolidation in all three joints
			Total	Partial	Not at all	Total	Partial	Not at all	Total	Partial	Not at all	
			86%	14%	–	50%	7%	43%	100%	–	–	50%
2–7 years	10	14	12	2	0	7	1	6	14	0	0	7
			94%	6%	–	56%	25%	19%	94%	–	6%	56%
7–12 years	13	16	15	1	0	9	4	3	15	0	1	9
			83%	17	–	58	17%	25	92%	–	8%	[illegible]
12–15 years	10	12	10	2	0	7	2	3	11	0	1	7
			88%	12	–	55%	15%	30%	95%	–	5%	55%
Total	33	42	37	5	0	23	7	[illegible]	40	0	2	23

60 per cent of the feet showed a residual varus position of the calcaneus though in nearly all cases of a mild degree even in patients with a recurrence

Radiographic results concerning the incidence of ankylosis of the arthrodesis are seen in Table 5 Calcaneotalar and calcaneo-cuboid arthrodeses ankylosed to the same extent in all age groups Talonavicular arthrodesis shows a somewhat lower incidence of ankylosis in the lowest age group By partial union is meant that there were signs of bony bridging but that a fissure was still visible in part of the joint From the available radiographs no certain signs of great alteration in skeletal growth could be seen which might be attributed to the subtalar arthrodesis Only the os naviculare seemed in several cases to be rather small and also deformed In a number of cases subluxation of the naviculare in relation to the talus was found

It would be of value to compare the clinical with the radiological results and in particular patients with recurrences and poor results have been analysed but the numbers are too small to be able to draw certain conclusions as to the connection between radiographical union and clinical result It should however be pointed out that in all cases classified as a poor result among them seven recurrences the calcaneotalar arthrodesis was united at least over the greater part of the area of contact in all cases the calcaneo-cuboid arthrodesis in 70 per cent but the talonavicular in only 50 per cent There was no certain difference between age groups On comparing the poor with the good results one finds among the latter a higher incidence of ankylosis of the arthrodesis Probably the absence of ankylosis in the talonavicular arthrodesis constitutes a *contributary* reason for a poor result but not the only one however 40 per cent of the totally ankylosed arthrodeses showed a supination deformity of the forefoot but one cannot exclude the possibility that some of these were not fully corrected in the first place A strong tibialis anterior and posterior together with absence of ankylosis in the talonavicular joint can be a cause of supination deformity of the forefoot Not unexpectedly the two youngest patients were among the recurrences but were subjectively troublefree one operated upon bilaterally at 2½ years of age the other unilaterally at 3 Of these three feet one of the bilateral arthrodeses was completely united the other two partly so The other patients in the 2½–7 age group were operated upon from 5 years of age upwards and the results in these did not differ markedly from those in the older age groups

One group of patients is particularly to be noted *i.e.* those with other

TABLE 6

Follow-up Examination of Operated Patients with other Congenital Anomalies and Debilities

Age at operation	Number of patients	Number of feet	Subjective results			Objective results		
			Good	Fair	Poor	Good	Fair	Poor
			14%	86%	—	14%	57%	29%
2 ½–7 years	4	7	1	6	0	1	4	2
			17%	17	66%	—	34%	66%
7 12 years	4	6	1	1	4	0	2	4
			—	—	100%	—	100%	—
12 15 years	1	2	0	0	2	0	2	0
			13%	47%	40%	7%	53%	40%
Total	9	15	2	7	6	1	8	6

congenital deformities and some mentally retarded patients. Nine such patients with 15 club feet were followed up as described earlier. The results in this group are outstandingly bad. Only one out of 15 feet could be classified as a good result. All four recurrences in the 7–12 age group, two recurrences in the 2½–7 age group and one other poor result in the same age group are to be found among these patients. The two recurrences in the youngest age group were both in the 2½ year old child. Five of the seven still using orthopaedic shoes or braces belong also to this group, though in some cases these are necessitated by the other congenital deformities.

On comparing the primary result with the final result the following observations are prominent. *The primarily good results, best in the 7–12 age group*, deteriorated clearly later on. The incidence of radiological union rose, however, most strikingly in the youngest age group (cf. Tables 1, 2 and 3). On the other hand, the four primarily unsatisfactory cases in the youngest age group are found unaltered in the final results.

THE CONTROL GROUP

These were uncomplicated cases of unilateral club foot, the original degree of severity of which cannot be classified in retrospect. The 20 feet were treated conservatively by manipulation and plaster and six underwent subcutaneous achilles tenotomy. No other operative measures were taken. Assessment of the final result was on the same principles as for the operated feet.

On assessment of the *subjective* result, 17 of the 20 had a good result and the other three a satisfactory result. Three patients had a feeling of *restricted movement in the ankle joint*, which was *not*, however, disturbing. Eight had certain difficulties in buying shoes on account of different sized feet. None had trouble from the first metatarso-phalangeal joint.

On *objective* assessment, eight patients had a good and twelve a satisfactory result. Deterioration of the result was due in seven cases to adduction of the forefoot, in three to moderate valgus position of the heel and in two cases to moderate varus deformity. As is seen from Table 3 the affected feet and the leg on the affected side were shorter than their fellows. Range of movement in the ankle joint was on average 48°, and seven patients had equinus. None had weakness of the toe extensors, and all had normal movement in the first metatarso-phalangeal joint. None had any supination deformity of the forefoot. Peroneus

function was normal in 18 patients and weakened in two powerful tibialis anterior function was found in two cases and atrophy of the calf muscles in varying degree in all cases

DISCUSSION

In evaluating the therapeutic effect of subtalar arthrodesis in the correction and stabilization of the equinovarus deformity in congenital club foot in children the discussion proceeds from the premise that ankylosis of the subtalar joints is a prerequisite in preventing recurrence Several questions which are of interest in this connection are dealt with here

1) Can a subastragalar arthrodesis ankylosed in a primary good position always prevent recurrence and poor result?

Of the completely ankylosed arthrodesis approximately 40 per cent showed a supination deformity of the forefoot Among the cases with complete radiological union on taking off the plaster post operatively and therewith good clinical result are found two recurrences Deterioration of primarily good operation results has been reported by several authors and in arthrodeses in paralytic equinovarus feet among others (3 7) Information concerning the incidence of ankylosis in recurrences is however scarce

The question may therefore be answered thus An apparently ankylosed arthrodesis of the subtalar joints cannot prevent the occurrence of a malposition affecting the forepart of the foot The risk of recurrence may be judged to be greater in primarily unsatisfactory corrections of the foot

2) What factors may cause recurrence and poor results in united arthrodeses?

Here we must differentiate between primarily unsatisfactory position of the foot due to insufficient correction at operation and changes occurring secondarily The great value of primary full correction in particular of the calcaneus position has been mentioned by several authors Weak and contracted toes significantly worsen the functional result and seem moreover to contribute to the appearance of secondary deformities The most common cause of recurrence probably consists of muscle imbalance which finds expression also in this series (Table 4) Patients with powerful tibialis anterior function and absent or weak toe extensor function are obviously liable to recurrence and deformity of the forefoot Furthermore uncorrected adductus deformity of the

forefoot is a factor in impairing the result. In patients with multiple congenital abnormalities and mental retardation, where these prevent the foot from bearing weight in the normal way, contractures can further contribute to the occurrence of deformities.

The answer to the question is thus:

Residual muscle imbalance, decreased toe extensor function, hallux flexus and hallux rigidus, insufficient primary correction with continued varus affliction of the foot, uncorrected adduction of the forefoot and also alterations in bone growth can be reasons for a deterioration in a primarily good operation result.

3) From what age can one count on ankylosis of the arthrodesis and a good clinical result?

This question has been the object of great differences of opinion. Michel (1930) (19) reported 12 good results in 11 children operated from 3½–6 years of age and 11 of these with total ankylosis; the observation time was 4 months to 3½ years, average 1½ years. *Hopf* (1954) (12) reported five poor results in 43 feet and was of the opinion that the earliest age was between 8 and 12 years. *Morris* (1933) (20) set 7 years and *McAusland* (1929) (18) and *Jones* (1908) (14) 10 years as the lowest age limit. *Roetter* (1948) (24) reported 35 feet operated upon between 3 and 15 years of age, of which 62.7 per cent had poor, 31.5 per cent satisfactory and 5.8 per cent good results.

On comparison of the age groups in this series no certain difference is found between ages. If one removes the two youngest patients, 2½ and 3 years old, from the youngest age group, the incidence of ankylosis of the whole arthrodesis is about the same for the remainder as for the two older age groups, i.e. 55–60 per cent. The clinical results in the 3 age groups are likewise alike: approximately 25 per cent good, 50 per cent satisfactory and 25 per cent poor results. Comparing the results of subtalar arthrodeses performed over the age of 15 one finds here also 25 per cent unsatisfactory cases. It is, however, difficult to compare the different series due to often insufficiently specific information.

In any case it can be said that 75 per cent of the operated patients have attained a material subjective and objective improvement compared with their condition before operation. The patients forced to wear orthopaedic boots decreased from 77 per cent before to 22 per cent after operation.

The question may therefore be answered thus:

If there is no therapy other than arthrodesis which can correct and

stabilise an intractable club foot then the operation may be performed from 5–6 years of age except in the cases of patients with multiple congenital deformities and or mental retardation in whom the age limit should be set higher preferably nearer puberty

4) Is correction and stabilisation of the hindfoot of use to the patient even if only part of the arthrodesis unites?

As can be seen from Table 5 the arthrodesis between calcaneum and talus united in all cases Stabilising of the hindfoot is considered to be of decisive importance in the treatment of club foot provided that full correction of the deformity can be achieved at operation

The question can thus be answered in the affirmative

5) Does the arthrodesis operation give rise to secondary deformities in the tarsus as a cosequence of alterations in bone growth?

Radiological examination has given grounds for believing that certain secondary changes in the pedal skeleton may be due in some few cases to changes in growth These are principally localised to the navicular which also shows subluxation in some cases In most cases however no material changes could be observed Evaluation of these changes could not be made from the information available from this series

A notable point is that none of the patients had pain in the foot on weight bearing attributable to the absence of ankylosis in the subtalar joints The subjective troubles could be attributed to diminished movement and or pain in the first metatarso-phalangeal joint hallux flexus skin callouses and feelings of diminished mobility in the ankle joint The average range of movement in the tibio-talar compartment of the ankle for the operated patients was for the different age groups 25 for 2–7 years 24 for 7–12 and 27 for 12–15 years In the unoperated feet the range of movement was 48 on average The range of movement in the ankle is thus not influenced by the time of operation but probably depends among other things upon deformation of the talus (9) Subtalar arthrodesis has no great effect upon the length of leg or size of foot Rigidity of the first metatarso-phalangeal joint and hallux flexus occurred in 40 per cent of operated cases but not at all in the conservatively treated feet Nor did weakness or absence of extensor function in the big toe or the small toes occur in these latter although found in 35 per cent and 60 per cent respectively of operated feet The operated material cannot be fully compared with that treated conservatively as the degree of severity of club foot is different Hallux flexus probably depends on a contracture of the long flexor tendon to the big toe and an operative lengthening of the tendon at an early stage

would seem to be desirable. The diminished extensor function of the toes could depend in some cases upon damage to the tendons inflicted at operation, which it should be possible to avoid by more careful operative technique. Subastragalar arthrodesis is a technically difficult operation which requires great care and practice. The foregoing series is a collection of cases operated upon by many different surgeons, so that a poor result from any one operation cannot always be blamed on the method, but may depend, in certain cases, upon defective execution.

In summary, it may be said that triple arthrodesis as a treatment for resistant club foot in childhood appears to be a method which, with adequate technique, is not as bad as has been asserted in so many quarters. One should be reluctant to use it in patients with multiple skeletal deformities and mentally retarded patients, in whom the prognosis is significantly poorer than for others. Before deciding on triple arthrodesis, however, one should try all forms of conservative treatment, together with lengthening of the Achilles tendon. Transposition of the tibialis anterior and possibly posterior tendon is reasonable, possibly together with the arthrodesis. As regards a Dwyer calcaneus osteotomy, this can be performed at even earlier ages than the subtalar arthrodesis. By performing subtalar arthrodesis relatively early, one can give the patient a chance to wear ordinary shoes. Function is usually such that the patient can play freely and take part in sports much earlier than if one waits till the age of puberty before performing definitive surgery. An early subtalar arthrodesis also spares the parents worry.

SUMMARY

From a series of 863 cases of congenital club foot, 55 feet were operated upon between the ages of 2½ and 15 years by triarticular subastragalar arthrodesis. Of these, 33 patients with 42 club feet were followed up after 2 to 14 years, average 9 years. The subjective and anatomical results were good or satisfactory in approximately 75 per cent of cases. The youngest age at which subtalar arthrodesis can be performed with a prospect of lastingly good results is claimed to be 5–6 years.

RÉSUMÉ

D'une série de 863 cas de pied bot congénital, 55 pieds ont été opérés entre l'âge de 2½ ans et 15 ans par arthrodèse triarticulaire sous-astragalienne. Sur ceux-ci 33 malades avec 42 pieds bots ont été réexaminés

nes au bout d une periode variant entre 2 et 14 ans et qui a été en moyenne de 9 ans Les resultats subjectifs et anatomiques ont ete bons ou satisfaisants dans environ 75 pour cent des cas Le plus jeune age auquel l arthrodese sous astragalienne peut etre pratiquee avec la perspective de bons résultats est estime etre 5–6 ans

ZUSAMMENFASSUNG

Aus einer Reihe von 863 Fällen von angeborenem Klumpfuss wurden 55 Fusse im Alter von 2½ bis 15 Jahren mittels einer triartikularen subtalaren Athrodese operiert Von diesen wurden 33 Patienten mit 42 Klumpfussen nach 2 bis 14 Jahren Durchschnitt 9 Jahren nachuntersucht Die subjektiven und anatomischen Ergebnisse waren gut oder zufriedenstellend in ungefahr 75 Prozent der Falle Das fruheste Alter in dem die subtalare Arthrodese mit Aussicht auf ein dauernd gutes Ergebnis ausgefuhrt werden kann liegt zwischen 5–6 Jahren

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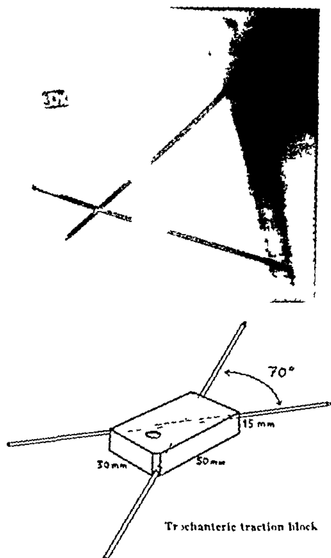


Fig 1

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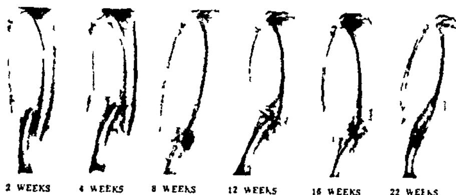


Fig. 1

Radiographs of the fracture specimens at various times after the fracture. Mineralized tissue can be demonstrated mainly on the muscular side of the bone fragments. The density of the callus increases rapidly, whereas the fracture line between the fragments is still visible at 12 weeks. Note the re-modelling of the fracture area during 8–22 weeks with rearrangements of the trabecular network in accordance with the static load on the bone.

units (*Rokkanen & Slätis* 1964). In the present paper a histo-quantitative analysis of the normal repair of fractured long bones is presented.

MATERIAL AND METHODS

Sixty white adult female rats were used. The right lower leg was fractured subcutaneously according to the technique of *Ernst & McLean* (1941). The leg was not splinted. The animals were sacrificed 1 to 22 weeks later; the fracture specimen was cleaned of soft tissues, radiographed and examined histologically. Prints were made of the radiographs at × 5 magnification, the boundaries of the visible callus outlined and the area thus obtained measured by planimetry. The callus was histologically examined and quantitative determination of the callus components made according to the line sampling method previously described (*Rokkanen & Slätis* 1964).

RESULTS

Radiographic Changes

Plain radiographs of the fracture revealed visible callus 2 weeks after the trauma. The bulk of this callus was found on the posterior facies of the tibia. At 4 weeks the density of the callus had increased, although the fracture line was still clearly visible. At 8 weeks the fracture line was less marked and the bone ends had become rounded and partly resorbed. At 16 weeks the fracture was roentgenologically united and at 22 weeks the remodelling of the bone at the fracture site was well advanced (Fig. 1).



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THE NORMAL REPAIR OF EXPERIMENTAL FRACTURES

A Histo-quantitative Study of Rats

By

P. SLÄTIS and P. ROKKANEN

The repair of a fracture of a long bone is brought about by the osteogenic tissue present in the periosteum and the endosteum, the osteogenic cells of the Haversian system, and presumably also by undifferentiated surrounding mesenchymal cells (*Urist & McLean* 1941, *Pritchard & Ruzicka* 1950, *Ham & Harris* 1956). The initial proliferative response in the periosteum is seen 16 hours after the trauma (*Tonna & Cronkite* 1961) and calcified bone is histologically recognizable two or three days after the fracture, being laid down under the periosteal collar at a distance from the fracture site (*Urist & McLean* 1941). In experimental animals the callus gains considerable tensile strength within 20–30 days, although the remodelling of the new bone takes place at a much slower rate (*Falkenberg* 1961). Both in experimental animals (*Bohr* 1955) and in man (*Wendeberg* 1961) the remodelling of the callus, as judged from studies with bone-seeking isotopes, continues for several months.

Although the histological course of events in the repair of fractures is well documented, few reports are available regarding the quantitative relations of the various tissue components in the callus during the repair process. *Koskinen* (1959) determined the amounts of the different tissue components in the callus under various experimental conditions using the line sampling method (*Uotila* 1940). The method was further developed by us in a previous paper and enables determination of the tissue components with a methodical error or less than 5 per cent.

This work has been aided by an institutional grant from the Sigrid Jusélius Foundation, Helsinki, to the Department of Forensic Medicine, University of Helsinki.



Fig. 1

Radiographs of the fracture specimens at various times after the fracture. Mineralized tissue can be demonstrated mainly on the muscular side of the bone fragments. The density of the callus increases rapidly, whereas the fracture line between the fragments is still visible at 12 weeks. Note the remodelling of the fracture area during 8–22 weeks with rearrangements of the trabecular network in accordance with the static load on the bone.

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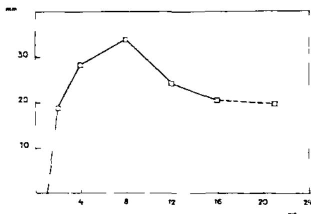


Fig 2
Planimetry of the radiographs at various times after the fracture

Planimetry of the Radiographs

The size of the roentgenologically demonstrable callus at various times after the fracture is graphically depicted in Fig 2 There was a steep increase in the callus area during the first weeks after the trauma the peak value being recorded at 8 weeks After this point the callus area gradually diminished although it was still of considerable magnitude at the end of the experiment

Histological Examination

The histological changes observed were essentially the same as those reported in a previous paper (*Rokkanen & Slätis* 1964) to which the reader is referred for details The main changes observed may be summarized as follows

During the first 4 8 weeks the most distinctive feature of the repair process was the intense proliferation of the osteogenic layer of the periosteum giving rise to the main part of the initial callus around the fractured bone ends This callus was predominantly composed of cartilaginous and fibrous tissue and to a lesser degree of new bone first demonstrable under the periosteal collar The process of mineralization then proceeded gradually towards the central part of the callus the cartilaginous and fibrous tissues being successively replaced by spongious bone

From 8 to 22 weeks after the fracture there was little change in the histological picture of the callus The mineralization of the central parts

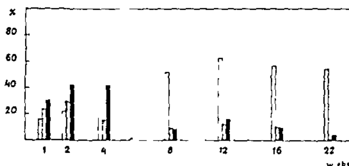


Fig 3

Histo quantitative analysis of the callus tissue at various times after the fracture of a long bone expressed as percentages of the total area
White column new bone Hatched column cartilaginous tissue
Black column Fibrous tissue

continued although cartilaginous tissue was still clearly demonstrable between the broken bone ends 16 weeks after the fracture At this time however bony union between the fragments was regularly observed in the periphery of the callus The spaces between the trabeculae became narrower as the new bone tightened up around the fractured bone ends This remodelling of the callus was the most noticeable histological feature during the late stage of fracture repair

TABLE 1

Relative Amounts of Main Tissue Components in the Callus Expressed as Percentage at Various Times after the Fracture of a Long Bone

Time after fracture	New bone (*per cent*)	Cartilaginous tissue (*per cent*)	Fibrous tissue (*per cent*)
1 week	16	24	30
2 weeks	22	29	42
4 weeks	25	16	42
8 weeks	52	10	9
12 weeks	62	12	16
16 weeks	56	10	10
22 weeks	55	0 3	4

Histo quantitative Analysis of the Callus

The relative amounts of the main tissue components present in the callus at different times after the fracture are graphically depicted in Fig 3 During the first four weeks the proportion of new bone was low

but increased continuously and reached a peak value at 12 weeks. At this point the new bone was the major constituent (62 per cent) of the total callus and this dominance persisted during the subsequent course of the experiment.

During the first four weeks the cartilaginous and fibrous tissue made up more than half the callus. The proportion of cartilaginous and fibrous tissue diminished rapidly, however, from the fourth to the eighth week and gradually fell to a value of less than 5 per cent of the total amount of callus tissue by the end of the experiment.

DISCUSSION

The advantage of histo-quantitative studies in connection with investigations on fracture repair is two-fold. First, it provides information on the composition of the callus at various times after the fracture. Secondly, it permits comparison of callus tissue formed under different experimental conditions (*Koskinen* 1959, *Rokkanen & Slätis* 1964). In the present investigation a quantitative examination of the main callus components was performed without any attempt at an analysis of the specific cellular reactions during fracture repair. Special problems regarding the mineralization of bone and the ultrastructure of bone formation and resorption are obviously better studied with the aid of bone-seeking isotopes and a microradiographic technique.

The histo-quantitative analysis of the callus at various times following a fracture showed that the proportion of new bone increases steadily during the first 12 weeks. This corresponds well with earlier investigations (*Nilsonne* 1959, *Falkenberg* 1961). During the first month, however, the part played by newly formed bone is small and during this stage the callus is predominantly composed of cartilaginous and fibrous tissue. By contrast, after the first month the new bone becomes dominant, whilst the proportion of cartilaginous and fibrous tissue rapidly decreases.

Thus, from a histo-quantitative point of view, fracture repair seems to be biphasic in character. During the first phase of fracture repair the bone ends are held together by a mass of soft tissue. During the second phase mineralization becomes the dominant feature. The spongious bone laid down is gradually tightening up around the fragments, eventually forming a structure closely resembling the surrounding cortical bone.

Falkenberg (1961), investigating the tensile strength of the callus in

rabbits demonstrated that fracture healing is achieved in the first place by a relatively rapid increase in the absolute tensile strength of the callus while the specific tensile strength of the callus increases at a slower rate. Correspondingly *Nilsonne* (1959) showed that the final bony union between the fractured bone ends occurs at a late stage and this was also confirmed histologically in the present investigation.

The biphasic nature of fracture repair obviously reflects the functional properties of two callus tissues of different composition. During the first phase, as judged from the histo-quantitative analysis, a provisional callus is rapidly formed between the fractured bone ends allowing early weight bearing at a time when the bone bridges between the bone ends are still incomplete. The second phase of fracture repair including the remodelling of the spongious callous bone is a slow process lasting several months and occurs at a time when functionally the fracture has already healed.

SUMMARY

The repair of experimental fractures of the long bones has been investigated in 60 female white rats. The fracture area was investigated roentgenologically, histologically and histo-quantitatively from 1 to 22 weeks following the trauma. The results may be summarized as follows:

1. Radiographically new bone can be detected in the callus areas 2 weeks after the trauma. Planimetry of the radiographs reveals a continuous increase of the visible callus area for 8 weeks, after which the callus area gradually decreases.

2. Histologically the essential feature in fracture repair is the intense proliferation of the osteogenic tissue covering the bone, especially of the periosteum. This gives rise to a mass of tissue around the fractured bone ends. This callus is mainly composed of cartilaginous and fibrous tissue although new bone is laid down during the first week under the periosteal collar. Subsequently mineralization proceeds towards the central part of the callus area, bringing about a trabecular network of spongious bone around the fracture.

3. Histo-quantitative analysis of the main tissue components in the callus makes possible a division of the repair process into two phases.

During the first phase the immature callus is composed mainly of *cartilaginous and fibrous tissue*, whereas the proportion of new bone, although steadily increasing, remains small.

During the second phase new bone constitutes the prevalent tissue component while the proportion of cartilaginous and fibrous tissue is minute and diminishes still further during the late stages of repair

RESUME

La restauration de fractures expérimentales des os longs a ete etudiee chez 60 cobayes femelles La surface de la fracture a ete examinee radiologiquement histologiquement et histo-quantitativement entre 1 et 22 semaines apres le trauma Les resultats obtenus peuvent etre resumes comme suit

1 Au point de vue radiologique une nouvelle formation osseuse peut etre decelée dans la surface du cal 2 semaines apres le trauma La planimetrie des radiographies revele une augmentation continue de la surface visible du cal pendant 8 semaines apres quoi la surface du cal diminue graduellement

2 Au point de vue histologique le fait essentiel de la restauration de la fracture est l intense proliferation du tissu osteogenique qui couvre l os specialement dans le perioste Cela donne lieu a une masse de tissu autour des extremites osseuses fracturees Le cal se compose principalement de tissu cartilagineux et fibreux bien que la nouvelle formation osseuse se fasse pendant la premiere semaine sous le collier periosteal Une mineralization subsequente s opere vers la partie centrale de la surface du cal formant un reseau trabeculaire d os spongieux autour de la fracture

3 Une analyse histo-quantitative des principaux composants du tissu du cal permet de diviser le processus de restauration en deux phases Durant la premiere phase le cal precoce se compose essentiellement de tissu cartilagineux et fibreux alors que la proportion d os nouveau reste faible bien qu augmentant constamment

Durant la seconde phase le tissu osseux constitue le composant dominant alors que la proportion de tissu cartilagineux et fibreux est faible et continue a diminuer pendant la derniere phase de la restauration

ZUSAMMENFASSUNG

Die Heilung von experimentellen Brüchen der langen Knochen von 60 weissen weiblichen Ratten wurde untersucht Das Bruchgebiet wurde rontgenologisch histologisch und histo-quantitativ von der 1 bis 22

Woche nach dem Trauma untersucht. Die Ergebnisse können in folgender Weise zusammengefasst werden:

1. Röntgenologisch kann neuer Knochen im Kallusgebiete 2 Wochen nach dem Trauma entdeckt werden. Planimetrie zeigt eine fortlaufende Zunahme des sichtbaren Kallusgebietes während 8 Wochen. Hernach nimmt die Kallusfläche gradweise ab.

2. Histologisch ist der wesentliche Zug der Bruchheilung die intensive Proliferation des den Knochen deckenden osteogenetischen Gewebes, besonders des Periostes. Dies führt zu einer übermässigen Gewebsbildung um die gebrochenen Knochenenden. Dieser Kallus besteht hauptsächlich aus kartilaginösem und fibrösem Gewebe, obwohl auch neuer Knochen während der ersten Woche unter dem Periostkragen angelegt wird. Nachfolgend schreitet die Mineralisierung gegen die zentralen Teile des Kallusgebietes fort und lässt ein trabekulares Netzwerk von spongiösen Knochen um den Bruch entstehen.

3. Gewebs-quantitative Analyse der hauptsächlichen Gewebskomponenten im Kallus ermöglichen eine Aufteilung des Heilungsprozesses in zwei Phasen. Während der ersten Phase besteht der unreife Kallus hauptsächlich aus kartilaginösem und fibrösem Gewebe, während der Anteil von neuem Knochen, obwohl ständig zunehmend, gering bleibt. Während der zweiten Phase stellt neuer Knochen die vorwiegende Gewebskomponente dar. Der Anteil von kartilaginösem und fibrösem Gewebe ist dagegen sehr klein und verringert sich noch mehr während der späten Heilungsstadien.

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THE REACTION OF BONE TO EXPERIMENTAL CANCER

By

A HELLEM and S OLERUD

In skeletal metastasis of carcinoma it is usual to distinguish between osteoblastic and osteolytic metastases As a rule however new bone is formed and old bone decomposed at the same time although to a varying extent (*Milch et al* 1956) Metastases from a prostate cancer for example may be both osteolytic and osteoblastic at different sites in one and the same patient (*Jaffe* 1958) In successful endocrine treatment of osteolytic metastases these metastases become osteoblastic (*Coley* 1949) It is not entirely clear how the osteolysis takes place It has been discussed whether it is the pressure from the tumor which produces necrosis in the bone or whether the cancer cells emit some osteolytic substance On the other hand most authors are agreed that few osteoclasts occur in this osteolysis In experimental tumours *Gorham* (1960 1964) noted that bone resorption occurs at sites where there is hyperemia on account of their nearness to the tumour while *new bone is formed on the side opposite the tumour where according* to this author the blood supply is scanty

In the present investigation we wished to study in more detail the conditions under which bone resorption and the formation of new bone take place when a cancer comes into close contact with bone The experiments were primarily intended to make clear the bone changes caused by the direct invasion of an adjacent cancer (for example in the pelvis in a case of cancer of the bladder) rather than the changes which arise from bloodborne metastases

We used the V×2 carcinoma which can be inoculated homologously into rabbits It is a squamous cell cancer and was virus linked from the beginning For further information about this cancer we must refer the reader to *Tjeenberg* (1962) Like *Cerino et al* (1963) we studied the bone changes but used a number of different procedures ordinary X ray photography microradiography conventional histology investi

gation of alkaline phosphatase activity autoradiography using S^{35} and finally investigation by micro angiography and tetracycline induced fluorescence

MATERIAL AND METHODS

Rabbits of mixed breed weighing between 1 and 3 kg were used. The contents of a tumour from a rabbit were sucked out or excised The tumour was crushed to pieces against a fine meshed metal fabric and then suspended in saline The suspension was filtered several times through several layers of cotton gauze It was injected into each rabbit at three places viz against the parietal region of the cranium against the middle part of one femur and intra-osseously through a little hole drilled below the tuberositas tibiae Approximately 0 2–0.3 ml were injected at each point In these experiments we did not consider it necessary to administer an exact dose of the tumour material

Two days before being killed (usually 3 weeks after the start of the experiment) the rabbits received Ledermycin (Lederle) intra abdominally or intravenously In most cases micro angiography with Indian ink or Micropaque was performed in connection with the killing Polythene tubes were inserted via the aorta abdominalis partly in the proximal and partly in the caudal direction and through them the suspension was allowed to drip from a height of 150 cm

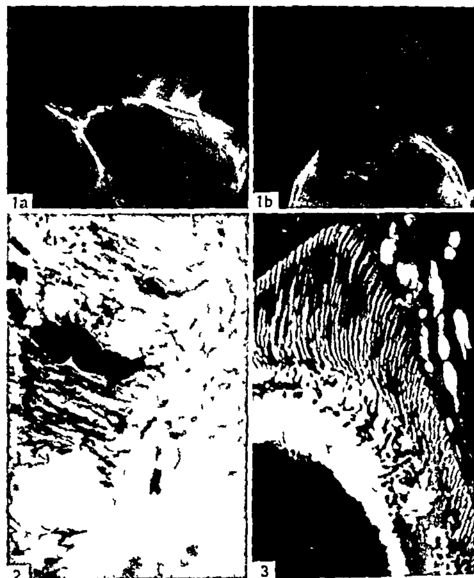
Four rabbits received S^{35} (Radiochemical Centre Amersham) in a dose of 0 5 millicurie per 100 g body weight Two of these animals received the dose 5 days before death and the other two 2 hours before death

After killing specimens of bone were immediately taken for histochemical and microradiographic examination Otherwise the animals were deepfrozen at −20 C for 24 hours after which the tumour bones were sectioned with a saw X ray photographs were taken of the entire bones and of the sections From these photographs specimens were selected for bedding in methyl metacrylate after fixation in alcohol Slices were sawn off and ground by hand to a thickness of about 125 μ These were examined by microradiography and then mounted under coverslips for fluorescence microscopy

Preparations were fixed in neutral formalin for histological examination Other preparations were fixed in a cold mixture of acetone and alcohol in order to show any alkaline phosphatase activity All decalcification was done in a mixture of formic acid and sodium citrate The preparations were embedded in paraffin wax sliced into sections 10–15 μ thick and stained with haematoxylin-eosin For autoradiography with S^{35} the preparations were fixed in formalin and autoradiographed by the stripping film technique (see *Engfeldt & Westerborn* 1960) A number of sections were pre stained with haematoxylin while the rest were unstained Every eight section in the series was stained in the usual way with haematoxylin-eosin The Gomori calcium-cobalt method was used to demonstrate alkaline phosphatase activity

RESULTS

As early as a week after the inoculation it was possible to palpate tumours at the sites at which the tumour tissue had been injected The



Figs 1–3

Fig 1a. Radiograph Spiculae formation radiating from the cranium especially in the periphery of the tumour

Fig 1b Radiograph Destruction of the cranium in the central part of the tumour

Fig 2 Microangiograph Vessel formation in the outer part of the tumour at right angles to the lamina externa of the parietal bone The new bone has formed spiculae Destruction of bone has just started (to the right) Magnification × 8

Fig 3 Microradiograph Transverse section of the tibia High spiculae formation in the neighbourhood of the tumour Marked halisteresis and incipient osteolysis The vessels are filled with Micropaque Magnification × 8



Fig 4
Photomicrograph Haematoxylin eosin Periosteal spiculae formation close to tumour growth Magnification × 50

tumours grew rapidly and after 3–4 weeks they were so large that in most cases they erupted through the skin A number of the animals died of marasmus sometime after this The tumours in the young animals showed a more rapid rate of growth than those in the old animals As a rule the animals were killed in the 3rd week and in this connection material was taken under sterile conditions from one of the animals for inoculating into fresh rabbits In general 3–5 animals were inoculated at a time From *ordinary X ray photography* it was easy to see the changes caused by the tumour in the bone After deep-freezing and sectioning the body as described above these changes could be studied in greater detail In several cases it was possible to see in the cranium distinct spiculae in the outer zone of the tumour In the central part of the tumour on the other hand there was often destruction of the cranium (see Fig 1 a b) On the femur the most common changes were large or small cortical deposits on the circumference of the bone These might be like spiculae in form but were sometimes lamellar On the tibia both osteoplastic and osteolytic changes were always found A

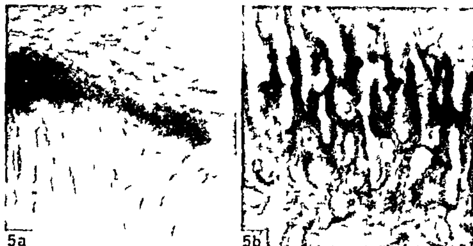


Fig 5

a Autoradiogram The labelled pre osteoblast area 2 hours after S^{35} injection Magnification × 20

b Autoradiogram Five days after S^{35} injection The bone formed at the time of injection shows up in the band across the spiculae Magnification × 20

constant phenomenon was that spiculae were developed to a particularly great extent on the fibula which was not subjected to any mechanical lesion during the implantation

The microscopic investigations yielded the following results The *bone proliferation is an initial phase in the bone's reaction to V×2 cancer* It can proceed as long as the surroundings are relatively intact Bone is formed around capillaries which are directed at right angles to the corticalis or the lamina externa Fig 2 shows a microangiogram and a tetracycline fluorescence picture of the cranium with both new formation of bone and incipient destruction of bone In sections which were taken at right angles to the bone surface this new formation has the appearance of spiculae (Figs 3 and 4) Spiculae may also develop within the marrow cavity in the direction of the endosteum which probably does not occur otherwise *The osteophytes tend to be larger at the sites of muscle attachments* (see *Fig 3 which is a microradiograph*)

At the site of bone formation with short term labelling with S^{35} (2 hours between injection and death) there is a diffuse labelling of the pre osteoblast area This labelling is therefore to be found mainly in the area in front of the growing spiculae (Fig 5 a). If 5 days are allowed to elapse between the injection of the radio sulphate and death



Fig 6
Photomicrograph The alkaline phosphatase activity well demonstrated in the area of newly formed bone To the right, the cortical bone with no activity Magnification × 20



Fig 7
Fluorescence photomicrograph from tibia Fluorescence of two tetracycline injections administered at an interval of 7 days Magnification × 20

the sulphur is found instead as a band right across the bone spiculae at the site corresponding to that of the bone which was in formation at the time of the injection (Fig 5 b) We find that the area of actual bone formation exhibits great alkaline phosphatase activity which is found

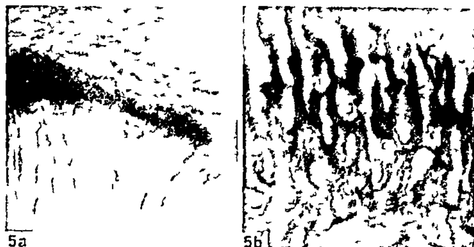


Fig 5

a Autoradiogram The labelled pre osteoblast area 2 hours after S^{35} injection Magnification × 20

b Autoradiogram Five days after S^{35} injection The bone formed at the time of injection shows up in the band across the spiculae Magnification × 20

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partly between the bone spiculae and partly in front of these spiculae in the preosteoblast area The osteoblasts and osteocytes in newly formed bone also show great alkaline phosphatase activity (Fig 6)

The bone which is being newly formed takes up tetracycline which produces fluorescence in the fluorescence microscope with UV light On the other hand no fluorescence is to be found in the original bone If tetracycline is administered repeatedly several fluorescence maxima will be found in the growing osteophyte (Fig 7)

In general it may be said that the new bone is formed in the vicinity of the tumour but not in close contact with it When the tumour comes too near the newly formed bone and grows through the fibrous wall which separates the spiculae from their surroundings this bone dies The tumour cells continue to grow down into the interspaces between the spiculae and often grow within the bone in the vascular canals often also intravascularly

Resorption of bone mainly occurs in three ways In the first place there is a dilatation of the vascular canals in the original bone near the tumour (Fig 8) This halisteresis is probably caused by the hyperemia In such cases it is possible to see dilated vessels in the osseous canals In the relatively well preserved mesenchyme nearer the tumours osteoclasts are developed to a certain extent and help to decompose the bone In the last resort—and this is the most important case—the tumour cells themselves may break down the bone after it has been cut off from its blood supply In this connection a diffuse ingrowth of the round tumour cells is found between the residual fragments of bone and by degrees the bone may disappear completely in large areas (Fig 9)

DISCUSSION

Stimulus to pathological growth or decomposition of bone is not linked with the bone s own tumours whether they are primary sarcoma or secondary metastases The present work shows that a tumour—V ×2 cancer—which does not have a natural tendency to grow in bone may produce strong reactions in the bone if it is given an opportunity to grow in close contact with the bone To begin with there is formation of new bone and then decomposition of bone which may result in the bone disappearing completely This applies especially when the tumour is inoculated intraosseously in the tibia but also to a great extent if it is applied closely to the cranium Owing to the fact that the tumour is growing in its vicinity the bone will probably suffer meta

bolic damage which will stimulate the surrounding mesenchyme to take repair measures in the form of the ingrowth of capillaries which always seem to grow at right angles to the surface of the bone and not towards the tumour. At the same time preosteoblasts are formed in the periosteum or outside the lamina externa of the calvaria in the area of the newly formed capillaries. Then bone is formed round the capillaries beginning nearest the bone surface and thereby this bone will have the appearance of spiculae on sections taken at right angles to the bone surface. The bone formed in this way is similar to other new bone for example fracture callus. There are however certain differences between newly formed bone at the site of the $V \times 2$ cancer and the newly formed bone during fracture healing. In a diaphyseal fracture the vessels are mainly directed towards the interfragmental area and even the periosteal vessels show the same tendency. Therefore the periosteal vessels have more acute angles to the corticalis at a distance from the interfragmental area (*Trueta* 1962, *Hulth & Olerud* 1964). The bone spiculae in the vicinity of the cancer may be also formed from the endosteal surface of the diaphysis and from the calvaria. Such a bone growth is never seen in the common type of experimental callus.

The pre-osteoblast area takes up S^{35} in short term labelling and if several days are allowed to elapse between the injection and death the radiosulphate can be found in the fully formed bone as a band right across the bone spiculae. The alkaline phosphatase activity is also great in areas of bone formation and in the osteoblasts and osteocytes of the newly formed bone. Tetracycline induced fluorescence is of course found in the newly formed bone (but may also be found in resorption cavities).

As the tumour continues its growth, the circulatory connections to the bone are broken off but the tumour continues to grow into the preformed cavities in the bone. Osteolysis takes place mainly in three ways. As long as the bone is relatively intact there occurs at a distance from the tumour a hyperemia which results in dilatation of the vascular canals which contain dilated blood vessels. Nearer the tumour in areas which have intact connections with the surrounding mesenchyme there is osteoclastic decomposition. However this phase is probably relatively short since the number of osteoclasts is never particularly large. When the bone is entirely disconnected from its surroundings and the tumour has free scope a very rapid and complete osteolysis takes place clearly caused by the ingrowing tumour cells themselves. The living tumour cells may conceivably emit substances which dissolve bone.

SUMMARY

When it is inoculated close to the bone or into bone V×2 cancer produces to begin with bone proliferation and then destruction of bone. The bone proliferation is similar to experimental fracture callus and is developed around newly formed capillaries. But these capillaries are mainly directed at right angles to the corticalis, whereas the capillaries in experimental fracture callus are directed towards the haematoma in the interfragmental area. The newly formed bone has a spiculae like appearance in the X-ray photographs. Such spiculae are also formed on the top of the skull or from the endosteal bone towards the marrow cavity, in which places this kind of new bone formation is otherwise never seen. When the tumour continues its growth, the vascular connections with the bone are completely destroyed and the bone dies and undergoes osteolysis. Before this however bone resorption has taken place through halisteresis or osteoclastic decomposition. The greatest destruction seems to be done by the cancer cells themselves.

RÉSUMÉ

Lorsqu'il est inoculé tout près de l'os ou dans l'os, le cancer V×2 produit pour commencer une prolifération osseuse, puis la destruction de l'os. La prolifération osseuse est similaire au cal des fractures expérimentales et se développe autour de capillaries nouvellement formés. Mais ces capillaries ont principalement une direction à angle droit par rapport à la couche corticale, alors que les capillaires du cal des fractures expérimentales se dirigent vers l'hématome dans la surface interfragmentaire. L'os nouvellement formé présente sur les photographies aux rayons X l'aspect d'un spicule. De tels spicules se forment aussi sur le sommet du crâne ou sur la face intérieure de l'os du côté de la cavité de la moelle, endroits où cette nouvelle formation osseuse n'a jamais été observée autrement. Lorsque la tumeur continue à se développer, les relations vasculaires avec l'os sont complètement détruites, l'os meurt et est voué à l'ostéolyse. Toutefois avant cela une résorption de l'os s'est effectuée par fonte halistérique ou par décomposition ostéoclaste. La plus forte destruction semble se faire par les cellules cancéreuses elles mêmes.

ZUSAMMENFASSUNG

Wenn V×2 Cancer nahe am Knochen oder in den Knochen eingepflanzt wird, ruft er zuerst Knochenproliferation und dann Knochen

zerstorung hervor Die Knochenproliferation gleicht experimentellem Bruchkallus und wird um neugeformte Kapillaren entwickelt Diese Kapillaren verlauften jedoch hauptsächlich rechtwinkelig zur Cortica lis wahrend die Kapillaren im experimentellen Bruchkallus gegen das Hämatom im Zwischenbruchgebiete gerichtet sind Der neugeformte Knochen hat ein spicula artiges Aussehen im Rontgenbilde Solche Spicula werden auch am Scheitel das Schädels oder vom endostalen Knochen gegen die Markhohle hin gebildet Stellen an denen diese Art der Knochenneubildung im ubrigen niemals gesehen wird Wenn der Tumor sein Wachtum fortsetzt werden die Gefässverbindungen mit dem Knochen vollstandig zerstort der Knochen stirbt ab und wird auf gelost Ehe dies eintritt hat jedoch Knochenresorption durch Halisterese oder osteoklastische Zersetzung stattgefunden Die grosste Zerstorung scheint durch Cancerzellen selbst herbeigefuhrt zu werden

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OXYTETRACYCLINE BONE LABELLING OF EXPERIMENTAL AFFECTIONS OF THE HIP JOINT

By

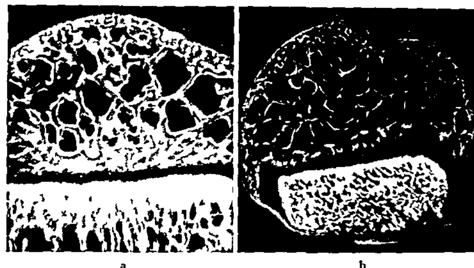
P Rokkanen P Slätis and H Laine

*Milch Rall & Tobie*s (1958) observations on the affinity of tetracycline for bone and *Frost Villanueva & Roth*s (1960) investigations on the use of tetracycline in bone physiology constitute the basis for a new research method by means of which the formation of new bone can be followed The tetracyclines produce a fluorescence observable both macroscopically and microscopically under ultraviolet light and demonstrable as much as six years after tetracycline administration (*Frost* 1963) Since tetracyclines in the bone tissue follow ionized calcium (*Finerman & Milch* 1963) they may to some extent supercede the radioactive isotopes By administering tetracycline at certain intervals the growth of the long bones during the corresponding period can be quantitatively determined (*Vanderhoeft Kelly & Petersen* 1962 and *Frost* 1963)

Using tetracycline *Woodhouse* (1962) demonstrated that an avascularized femoral head did not fluoresce *Milch* (1963) showed that as a result of osteoarthrosis the bone tissue became unevenly labelled with tetracyclines In agreement with these observation it could be demonstrated in a recently published study that necrotic bone does not fluoresce and that in regenerating bone areas such as osteophytes oxytetracycline produces strong fluorescence (*Rokkanen Slätis & Laine* 1963)

In the following our experience of this fluorescence technique in rabbits on which surgical interference with the femoral neck had been

This work has been aided by an institutional grant from the Sigrid Jusélius Foundation Helsinki to the Department of Forensic Medicine University of Helsinki



a b

Figs 1 a and b

a Fluorescence micrograph of a normal femoral head ground to 100 µ thickness according to Frost s method The OTC—fluorescence is evenly distributed in the epiphysis and heavily deposited in the metaphysis × 30

b Fluorescence micrograph of a normal femoral head The specimen was embedded in methylmetachrylate and ground to 60 µ thickness × 30

carried out will be related The aim was to compare the fluorescence pattern of the femoral head with the histological and radiological findings

MATERIAL AND METHODS

The series comprises 39 white rabbits of varying ages and of both sexes on the left hip of which the following measures had been carried out while the right hip acted as a control

1) On 15 rabbits the neck of the femur was tightly ligated with steel wire The follow up time for 8 young (8 week old) rabbits was from 1 to 28 week and for 7 adult (12 month old) rabbits 2? months

2) On 24 young (8 week old) rabbits total osteotomy of the femoral neck was carried out In 12 of these animals the ligamentum teres was simultaneously divided The animals were killed 1 to 20 weeks after the osteotomy

Oxytetracycline labelling Three days prior to sacrifice each animal was injected with 50 mg oxytetracycline (OTC)[1] per kilogram of body weight The animals were killed with Intraval® the hip joint was exarticulated and the head of the femur was sectioned in the frontal plane

[1] Terramycin® intramuscular Pfizer



a b

Figs 9 a and b

a Fluorescence micrograph 3 weeks after exarticulation tight ligation of the femoral neck and severance of the lig teres Oxytetracyclinefluorescence is seen in the femoral metaphysis but is lacking in the femoral epiphysis above the epiphyseal cartilage × 30

b Micrograph of the central area of the same epiphysis sh ws predominantly nucleated bone areas The trabecular structure is normal Loss of nuclei in some teons and the scanty quantity of marrow tissue in the cancellous spaces give some evidence of nutritional disturbances of the bone Histologically the femoral epiphysis is partiall necrotic × 100

Histological examination After FDTA decalcification histological preparations of all amples were made using Weigert van Gieson haematoxylin and periodic acid Schiff (PAS) staining

Radiological examination The specimens were radiographed immediately after the animal had been killed On the adult animals a radiographic examination was al made while they were still alive

Preparations of the undecalcified bone sections were made in two different ways Following the procedure of *Frost* (19 8) slices of bone were ground with water proof adhesive carborundum abrasive paper t a thickness of ca 100 µ (Fig 1 a) From other pecimens taken at the same time 60 to 80 µ thick methylmetacrylate lices were m de (Fig 1) The e were examined microscopically under ultraviolet light and were ph t graphed

In ultraviolet micr c y an HBO ? 0 (O ram) UV lamp and a BG 12,6 mm primary filter emitting 3660 Angstr m UV rays were u ed


a


b

Figs. 3 a and b.

a. Fluorescence micrograph 8 weeks after exarticulation, tight ligation of the femoral neck and severance of the lig. teres shows derangement of the trabecular structure especially in the central parts combined with unevenly distributed fluorescence. × 30.

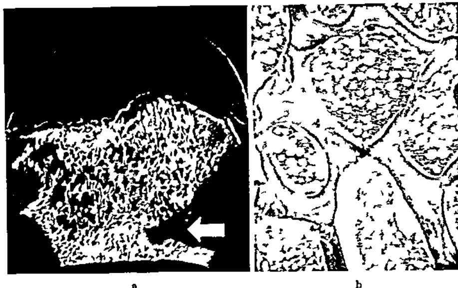
b. Micrograph of the central part of the same femoral head shows regenerative changes among the dead trabeculae. The cancellous spaces are filled with granulation tissue invading the femoral head from the metaphysis. × 100.

RESULTS

Tight Ligation of the Neck of the Femur

1 to 3 weeks after the operations, both nucleated and non-nucleated areas of cancellous bone were seen in the epiphysis of all the young animals, being an indication of degenerative changes. It could not, however, be concluded on histological grounds whether the epiphysis was wholly necrotic. During this period no noteworthy radiological changes were observed. Fluorescence micrographs showed OTC uptake on the operated side in the femoral neck but not at all in the epiphysis (Fig. 2a, b).

6 to 28 weeks after the operation strong regeneration was observed histologically among the dead trabeculae in the epiphysis. Radiologically a flattening of the femoral head was seen, while there were no changes in density. Fluorescence micrographs showed a more marked



a b

Figs 4 a and b

a Fluorescence micrograph 3 weeks after total osteotomy of the femoral neck shows an entirely non fluorescent epiphysis and strong fluorescence in the metaphysis and the femoral neck The line at the osteotomy site is seen (arrow) Note the fluorescence in the area between the osteotomy and the epiphyseal cartilage × 30

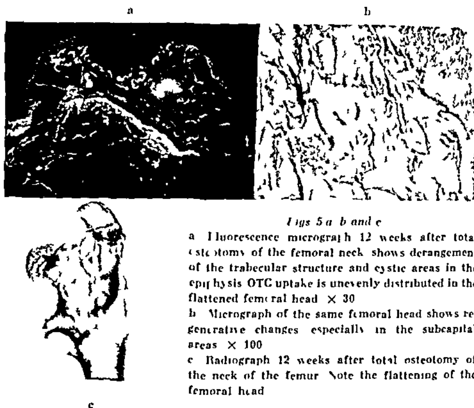
b Micrograph of the same femoral head shows both nucleated and non nucleated bone Histologically not decisive necrosis × 100

OTC uptake on the operated side Intensely fluorescent areas were often seen (Fig 3a b)

22 months after ligation of the femoral neck in adult animals histologically and radiologically demonstrable regenerative changes were observed in one out of seven animals only In all there was more marked fluorescence in the femoral head on the operated than on the intact side

Total Osteotomy of the Neck of the Femur

1 to 3 weeks after osteotomy of the femoral neck histological examination revealed that the epiphyseal cartilage in young animals was completely without nuclei In the epiphysis the cancellous bone had preserved its structure but here and there non nucleated bone areas were observed No changes could be demonstrated radiographically Fluorescence micrographs showed an entirely non fluorescent epi



Figs. 5 a, b and c

a. Fluorescence micrograph 12 weeks after total osteotomy of the femoral neck shows derangement of the trabecular structure and cystic areas in the epiphysis. OTC uptake is unevenly distributed in the flattened femoral head. × 30

b. Micrograph of the same femoral head shows regenerative changes, especially in the subcapital areas. × 100

c. Radiograph 12 weeks after total osteotomy of the neck of the femur. Note the flattening of the femoral head.

physis in five out of six animals. In one animal clear fluorescence was seen in the medial border of the epiphysis but in no specimen was it possible to demonstrate uptake in the area of attachment of the ligamentum teres (Fig. 4 a, b).

After 6 to 20 weeks there were histologically demonstrable regenerative changes, especially in the area of the neck. The epiphyseal cartilage often fused more quickly on the operated than on the intact side. Degenerative changes were often seen near the epiphyseal cartilage and less frequently in the area of the neck. In five out of eight animals the head of the femur was radiologically flattened, while there was no clear change in density (Fig. 5c). The fluorescence was regularly more intense on the operated than on the healthy side. Fluorescence of varying intensity and frequently in a patchy pattern appeared in the area of the epiphysis in all animals 6 weeks or more after the osteotomy.

DISCUSSION

In the present investigation the blood circulation in the area of the femoral head was impaired by ligation or complete osteotomy of the femoral neck combined in most animals with severance of the lig. teres. These procedures resulted in nutritive disturbances in the femoral head histologically demonstrable as anuclear areas of bone and later as invasion of granulation tissue in the cancellous spaces. The structural derangement of the femoral head was also evident from radiological flattening of the femoral head.

Comparison of the histological and radiological findings with the fluorescence pattern induced by OTC labelling revealed that bone rendered avascular by surgical interference was non-fluorescent. The lack of fluorescence was most evident in the early stages and the borderlines with living fluorescent bone easily recognized. OTC fluorescence recurred, however, at a later stage and corresponded to the histologically visible regeneration of the necrotic area.

Milch (1963) states that tetracycline labelling is a specific and suitable method for investigating the blood supply of the bone. Correspondingly, the lack of fluorescence in bone from which the blood supply is cut off seems to provide a simple and accurate method of early recognition of ischaemic disturbances of the bone.

SUMMARY

In 39 rabbits the degenerative and regenerative changes in the femoral head after various procedures directed at the neck of the femur has been investigated. Oxytetracycline labelling of the bone and histological and radiological methods were used in parallel in the investigation. Particular attention was attached to a comparison of the fluorescence phenomenon and the histological picture.

Avascularized bone in the femoral head and neck showed no fluorescence and was early distinguishable from the surrounding living bone. Histologically, the degenerative changes in the corresponding area did not become evident until 2–3 weeks after the interference.

Absence of fluorescence preceded the histologically demonstrable necrotic changes.

Regenerative changes were clearly noticeable with both histological and fluorescence techniques. Intense fluorescence followed upon for

mation of new bone. For many months after the interference the operated femoral head had a more intensive OTC fluorescence than the intact side.

RÉSUMÉ

Chez 39 lapins les modifications dégénératives et regénératives de la tête femorale après différents procedes appliqués au col du femur ont été examinés. Un label de l'os à l'oxytetracycline et des methodes histologiques et radiologiques ont été utilisées parallelement dans cette enquête. Il a été attaché une attention particulière à la comparaison du phenomene de la fluorescence dans le tableau histologique.

Un os avascularisé de la tête et du col fémoral ne presente pas de fluorescence et s'est montre très tot discernable de l'os vivant environnant. Au point de vue histologique les modifications degeneratives de la surface correspondante n'ont été apparentes que 2 à 3 semaines apres l'intervention.

L'absence de fluorescence précède les altérations nécrotiques histologiquement decelables.

Les modifications regénératives ont été clairement observables aussi bien avec la technique histologique qu'avec celle de la fluorescence. Une fluorescence intense suit la nouvelle formation osseuse. Durant de nombreux mois aprés l'intervention la tete femorale operée présentait une fluorescence OTC plus intense que le cote intact.

ZUSAMMENFASSUNG

Bei 39 Kaninchen wurden die degenerativen und regenerativen Veränderungen im Femurkopfe nach verschieden Eingriffen im Femurhalse untersucht. Oxytetracyclinmarkierung des Knochens sowie histologische und röntgenologische Methoden wurden bei der Untersuchung parallell miteinander verwendet. Besondere Aufmerksamkeit wurde dem Vergleich des Fluoreszenzphenomens mit dem histologischen Bilde zugewendet.

Gefässloser Knochen im Femurkopf und -hals zeigte keine Fluoreszenz und konnte frühzeitig vom umgebenden, lebenden Knochen unterschieden werden. Histologisch wurden die degenerativen Veränderungen in einem entsprechenden Gebiete nicht vor der 2.–3. Woche dem Eingriff sichtbar.

Das Fehlen der Fluoreszenz ging den histologisch nachweisbaren nekrotischen Veränderungen voraus.

Regenerative Veränderungen waren mit histologischer und Fluoreszenztechnik deutlich wahrnehmbar Intensive Fluoreszenz folgte der Bildung neuen Knochens Während vieler Monate nach dem Eingriff zeigte der operierte Femurkopf eine intensivere OTC Fluoreszenz als die intakte Seite

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mation of new bone. For many months after the interference the operated femoral head had a more intensive OTC fluorescence than the intact side.

RESUMÉ

Chez 39 lapins les modifications dégéneratives et regeneratives de la tete femorale après differents procédés appliqués au col du fémur ont été examines. Un label de l'os à l'oxytétracycline et des méthodes histologiques et radiologiques ont été utilisées parallelement dans cette enquete. Il a été attaché une attention particulière à la comparaison du phénomène de la fluorescence dans le tableau histologique.

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L'absence de fluorescence precède les alterations nécrotiques histologiquement décelables.

Les modifications regeneratives ont été clairement observables aussi bien avec la technique histologique qu'avec celle de la fluorescence. Une fluorescence intense suit la nouvelle formation osseuse. Durant de nombreux mois après l'intervention la tête femorale operée presentait une fluorescence OTC plus intense que le coté intact.

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Gefässloser Knochen im Femurkopf und -hals zeigte keine Fluoreszenz und konnte frühzeitig vom umgebenden lebenden Knochen unterschieden werden. Histologisch wurden die degenerativen Veränderungen in einem entsprechenden Gebiete nicht vor der 2–3 Woche dem Eingriff sichtbar.

Das Fehlen der Fluoreszenz ging den histologisch nachweisbaren nekrotischen Veränderungen voraus.



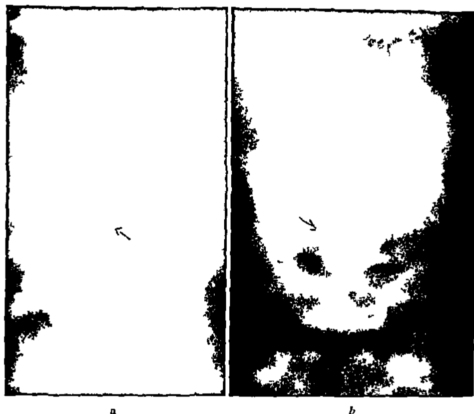
Fig 1

a Cervical column lateral view. Third disc reduced in height. Fourth cervical vertebra slightly dislocated dorsally. Oblique fracture through the posterior part of the lamina of the fourth cervical vertebra.

b Frontal view. Sagittal vertical fracture widest cranially through the body of the fourth cervical vertebra in the centre line.

OWN CASE

41 year old female. Since adolescence she had hypoglycaemic episodes which she had taught herself to stop by ingestion of sugar. Over the last year the attacks had assumed the character of dreamy states but they have never been accompanied by convulsion, loss of consciousness or fall. Four days before admission the patient lost consciousness for the first time during such an attack and fell backwards whereby she knocked the back of her head and her shoulder against a table. She regained consciousness immediately, had pains in the back of her head and her shoulder but no symptoms of concussion. On admission to the hospital she was unaffected. Some tenderness was found over the fourth and fifth spinous processes; the head could be moved freely sideways but hurt when lifted. Neurological examination, electroencephalography as well as ophthalmologic and otologic examination including audiogram and differentiated caloric test were normal. Blood sugar tests showed slightly lowered fasting values but additional examinations including serum insulin like



a b

Fig. 2

a. Frontal tomography. Sagittal cleaving of the body of the fourth cervical vertebra.
b. Frontal tomography. Oblique fracture through the medial part of the lamina of the fourth cervical vertebra.

activity determinations during glucose loading afforded no proof of insulinoma. It was concluded that the patient suffered from a hypoglycaemic dysregulation probably of hepatic nature.

Roentgenogram of the cervical column (Fig. 1 a–b) showed a vertical sagittal fracture of the fourth cervical vertebral body and a fracture in the arcus of the same vertebra without dislocation. The height of the third intervertebral space was slightly reduced and the back edge of the fourth cervical vertebra was displaced 2 mm dorsally. Tomography (Fig. 2 a–b) revealed a sagittal fracture of a maximum width of 3 mm cranially through the middle of the body of the fourth cervical vertebra and a fracture at the junction of the lamina and the spinous process in the right side without dislocation. Lateral tomography gave no further information. The intervertebral articulation were normal.

The patient was treated with plaster collar for nine weeks. Apart from a slight stiffness of the neck in the morning there were no complaints after the removal of the collar. Roentgenogram taken 6 months after the trauma (Fig. 3 a–b) revealed

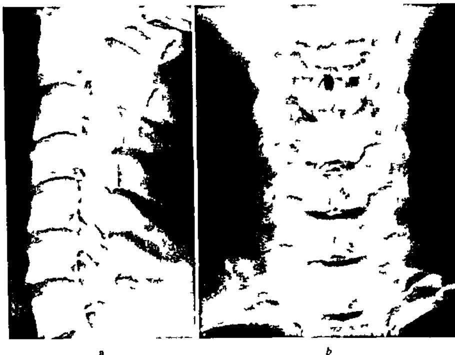


Fig 3

a Lateral view 6 months after trauma Slight reduction of height of the third cervical disc In ignificant dorsal di placement f the fourth cervi al vertebra with callus formati n (n its anteri r part

b Fr ntal vie like Fig 2 b the fracture still visible

onl a minimal dorsal di placement of the f urth cervical vertebra the third inter vertebral pace wa unchanged Some callus formati n was seen on the ventral side of the f urth cervical vert bra the fracture was still visible One year after the trauma the patient tate that she is c mpletely free of s mpt ms

DISCUSSION

The literature regarding fractures of the cervical column the me chanism of their aetiology and their distribution is extremely copious (cf inter alia *Pendergrass et al* ... *Jones Brocher Barnes Taylor & Blackwood Lob* and *Glorieux*) As regards the aetiology of the ver tical fracture of the cervical vertebral bodies *Blumensaat* is of the opinion that it is a question of an axial action of force through the cervical column through which the edge of the superjacent body exerts a chisel action on the subjacent vertebra whereby the latter is split when the column is in such a position that there is no possibility of

flexion or extension Against this theory *Stimpfl* point out that the discs of the cervical column are tall and project peripherally over the edge of the bodies He suggests that the nucleus pulposus causes the cleaving of the body provided that the trauma is directed absolutely axially so that the nucleus cannot escape in the peripheral direction (*Lob* Sprengwirkung des Gallertkerns) This happens very seldom and should explain why this type of fracture is so rare Against *Stimpfl*s theory *Blumensaat* (1953) reports one case where autopsy did not reveal intraspongious prolapse of the disc Also *Bourmer* reports one case where autopsy revealed rupture of the annulus fibrosus but no nucleus tissue was found in the vertebral body It may be supposed that the action of force is exactly strong enough to make the nucleus pulposus cleave the body of the vertebra so that the pressure decreases and the nucleus does not penetrate into the body itself However it is a fact that the vertical cervical fracture is a very rare type of fracture So far 25 cases are reported in the literature all of them single cases apart from *Blumensaat* (2 cases in 1948 and 1 in 1953) and *Richmann & Friedmann* who found 17 cases among 80 patients with fractures of the cervical column over a period of 5 years However their series comes from a paraplegia centre and consequently it is a selected material In most of the published cases the fracture was of the diving type—13 cases—(bathing or fall on the head) 7 occurred after motorcar accidents 3 after blows on the neck 1 after squeezing and in 1 case the mode or origin is not mentioned Most often the vertical fracture is localized to the fourth fifth or sixth cervical vertebra In *Richmann & Friedmann*s series 7 fractures were localized to the fifth cervical vertebra 6 to the sixth and 4 to the fifth and sixth cervical vertebrae Generally the lesions are complex so that apart from the cleaving fracture of the body other fractures or luxation are found simultaneously Thus among their 17 patients *Richmann & Friedmann* found only one case where vertical fracture was the only finding In 6 cases vertical fracture with compression was found while vertical fracture associated with compression dislocation and fracture of the lamina of various combinations was found in 10 cases The published cases show clearly that it is an extremely serious lesion Out of the 25 known cases 21 resulted in quadriplegia 6 of these 21 patients died Only 2 cases with slight neurologic symptoms have been published (*Wegener* and *Brocher*) while fracture without neurologic complications has been published only twice previously by *Ellis* and *Mansfield* each reporting one case

The roentgenologic diagnosis presents no greater difficulty when the incidence of this type of fracture is known. The preferred location of the fracture, however, makes it an insidious type of fracture, since the vertical line of the fracture can be overprojected by the air in the rima glottidis and thus escape notice. Another differential diagnosis is spina bifida anterior and posterior. In cases of doubt a tomography will reveal the diagnosis. *Richmann & Friedmann* point out that when the vertical fracture is localized to the centre of the vertebral body there is often no coexistent fracture of the vertebral arch, which on the other hand generally is found when the fracture is localized laterally in the vertebral body. In the present case, however, the vertical central fracture was accompanied by fracture through the lamina.

The extent of the lesion is elucidated by tomography and if possible by radiological function test, and is often much more extensive than suggested by ordinary survey films.

SUMMARY

One case of vertical fracture through the centre line of the body of the fourth cervical vertebra without neurologic symptoms is described. The patient was treated conservatively by means of a plaster collar and was asymptomatic at control examination one year after the accident. The previous literature comprising 25 cases is reviewed. In 21 of these cases there was quadriplegia with 6 deaths, in 2 cases relatively slight neurologic symptoms, while vertical fracture without any neurologic symptoms seems to be described only twice previously.

RÉSUMÉ

Un cas de fracture verticale à travers la ligne centrale du corps de la 4ème vertèbre cervicale sans symptome neurologique est décrit. Le malade a été soumis à un traitement conservateur au moyen d'un collier de plâtre et ne présentait aucun symptome à l'examen de contrôle un an après l'accident. La littérature antérieurement publiée comprenant 25 cas est passée en revue. Dans 21 de ces cas il y avait quadriplégie avec 6 décès, dans 2 cas des symptomes neuroliques relativement faibles, alors que la fracture verticale sans symptome neurologique ne semble avoir été décrite que deux fois auparavant.

ZUSAMMENFASSUNG

Ein Fall von vertikalen Bruch durch die Mittellinie des Körpers des 4. Halswirbels ohne neurologische Symptome wird beschrieben. Der Patient wurde konservativ mittels eines Gipskragens behandelt und war bei der Nachuntersuchung ein Jahr nach dem Unfall symptomfrei. Die vorangehende Literatur, die 25 Fälle aufweist, wird besprochen. In 21 dieser Fälle war Quadriplegie vorhanden, 6 davon starben, in 2 Fällen waren nur verhältnismässig leichte neurologische Symptome nachweisbar, während Vertikalbrüche ohne neurologische Symptome anscheinend nur zweimal früher beschrieben worden sind.

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DIASTEMATOMYELIA

Report of two Cases Submitted to Laminectomy

By

HUGO ANDERSSON and LARS SULLIVAN

Diastematomyelia is a rare congenital anomaly associated with spina bifida. The term was first used in 1892 to describe a split in the spinal cord resulting from experimental interference with frogs' ova (3). Because of the publication of a number of articles in recent years (1–14) it now represents a well known condition; however, to our knowledge no operated cases have previously been reported from Scandinavia.

Diastematomyelia simply means a bifid state of the spinal cord. The cord may be split by fibrous or bony tissue that extends from the vertebral body towards the lamina in the sagittal direction, or a similarly localized area may be divided longitudinally without associated interposed tissue. In the latter cases aberrant tissue or even neoplasms may rarely interpose. In the former case the two parts of the cord have a dural sheath of their own (11).

When a condition of complete doubling of the spinal cord exists in a localized sector it ought to be termed diplomyelia. This represents a different entity than the above described abnormity, diastematomyelia, which is in contrast only splitting or division of the spinal cord. However, many authors use the terms synonymously.

The majority of cases with diastematomyelia manifest no clinical signs. The pathological mechanism is considered to be prevention of the normal ascent of the spinal cord within the vertebral column. Lateral pressure from the splitting structure has also been suggested as an additional factor. These signs are mainly manifested by neurological deficits in the lower limbs, bladder and bowel, and often appear early in life, supporting the hypothesis that they result from traction due to the different growth rates of the cord and the spinal column. Still there are cases described in which the first symptoms do not appear until

adult life. In the group with a common dural sheath, operation has frequently revealed aberrant posterior nerve roots passing from the bifurcation of the cord to or through the dura to a neural arch. At transection it could be seen that they exerted a traction effect. Whether or not this traction per se can result in neurological deficits is poorly understood (11).

The clinical signs are not specific for diastematomyelia since they may also occur in different types of spinal dysraphism either alone or combined with diastematomyelia. The most frequent and earliest manifestation is usually retarded unilateral growth of one leg and foot often combined with a varus deformity. There may also be sensory loss, trophic ulceration and functional disability of the bowel and bladder. Even cases with paraplegia are reported.

When there are clinical signs of spinal dysraphism, a radiological investigation of the spine is indicated. Plain X-ray films in cases with diastematomyelia demonstrate widening of the spinal canal corresponding to the cleft bulbous widened cord and the extent of the spina bifida (which is most often occult) and sometimes additional anomalies like hemi- and fused vertebrae. If a sagittally directed bone septum is shown the diagnosis is definite. However, in cases with no interposition or with a fibrous septum not sufficiently calcified to show on radiographs, which is often the case in young children, myelography is needed for the diagnosis. This investigation is of further pre-operative interest as it gives information as to the site and extent of the anomaly. Gas myelography is the method of choice. It provides the most accurate anatomic delineation of the entire anomaly and it does not include the risk of arachnoiditis since the gas is quickly and totally absorbed. The latter advantage is especially worth considering when young growing patients are to be investigated, where impairment of the cord ascent could result.

Cases with diastematomyelia and neurological signs of spinal dysraphism require surgical correction of the anomaly. Because of the progressive character of the neurological deficits with the increasing risk of irreversible damage to the cord, this treatment should be as early as possible. Operative results showing some degree of improvement in two thirds of the patients with spinal dysraphism have been reported (10).



Fig 1

Clearly shows the underdevelopment of the left foot



Fig 2

Gasmyelography demonstrates the bulbous widening of the distal spinal cord through which the bony spur is traversing

CASE REPORTS

Case 1 1½ year old girl born with a spina bifida occulta associated with a large hairy mole over the lumbar region There was no family history of congenital anomalies At several months of age it was observed that the left foot was smaller than the right but there was no history of abnormal sphincter control

Physical examination at the age of 1 year revealed the child could not walk



Fig 3
Laminectomy performed
Arrow a) unopened dural sac
b) bony spur
c) dermoid cyst within bony *spur*

Fig 4
Dural sac opened
Arrow a) bony spur
b) right half of spinal cord
c) left side spinal cord
d) adhesions

Fig 5
Bone *spur* removed with its dural sheath
Arrow a) remnant of bone spur
b) dural sheath



Fig 6

Shows widening of the spinal canal in the lower dorsal and lumbar region associated with a number of vertebral anomalies The bony spur from Th 12 is indicated by the arrow

r stand the left lower extremity was smaller and the foot 1 cm shorter than the opposite side (Fig 1) The left achilles reflex was absent There was no paresis but slight equino varus deformity of the left foot was noted

Roentgen examination (Fig 2) showed multiple malformations in the thoraco lumbar region with hemivertebrae at T 11 and T 12 Bifid lamina at T 10 – L 2 associated with widening of the spinal canal in lower dorsal and lumbar region were present Gasmyelography revealed localized spindleshaped widening of the caudal spinal cord with an elongated central defect extending from lower part of Th 9 to L 2 A bony spur extending from the lower posterior body to the lamina of T 12 and traversing the middle portion of the defect could also be identified Intravenous pyelography was normal

Laminectomy revealed that the bony spur contained a small dermoid cyst associated with a sinus tract extending to the skin (Fig 3) The bony spur was enclosed in a dural sheath which was adherent to the adjacent spinal cord (Fig 4) Numerous adjacent adhesions were incised and the bony spur together with its dural covering resected (Fig 5)

Postoperative course was uneventful

Case 2 A nine month old male child was noted at birth to have a spina bifida occulta There was no family history of congenital malformations

Physical examination showed slight unilateral underdevelopment of the left lower extremity and moderate bilateral equino varus deformity Neurological examination was normal

Roentgen examination revealed localized widening of the spinal canal in the lower dorsal and upper lumbar region associated with several bifid laminae (Fig 6) Gasmyelography showed localized spindle shaped widening of the caudal spinal



Fig 7
Case 2 Dural sac opened
Arrow a) bonespur with dural sheath
b) lipoma in conus

Fig 8
Bone spur partly removed adhesions severed

Fig 9
Bone spur removed demonstrating the defect in the spinal cord

cord with an elongated central defect which was traversed by a bone spur arising from T 12

Laminectomy showed a bone spur similar to the previous case which was again enclosed in a dural sheath and associated with numerous adhesions to the adjacent cord (Figs 7 8 9) There was an incidental finding of a small lipoma in the conus medullaris The adhesions were incised and the bony spur and dural sheath resected No attempt was made to remove the lipoma

Postoperative course was uneventful

SUMMARY

A short review of the main features and the treatment of diastematomyelia is presented and two cases submitted to laminectomy reported The advantage of gasmyelography because of its superior delineation of the entire cord lesion and freedom from complicating arachnoiditis is emphasized

RÉSUMÉ

Un court aperçu des principales caracteristiques et du traitement de la diastematomyelie est presente et deux cas soumis a une laminectomie sont rapportes L avantage de la myelographie gazeuse est souligné en raison de sa delinéation superieure de la lésion entiere et il est souligne qu elle ne produit pas de complications de nature de l arachnoidite

ZUSAMMENFASSUNG

Eine kurze Übersicht der Hauptzuge und der Behandlung der Diastematomyelia wird gegeben und uber zwei Falle die einer Laminektomie unterworfen wurden wird berichtet Der Vorteil der Gasmyelographie wegen ihrer überlegenen Aufzeichnung der gesamten Strangbeschädigung und wegen des Nichtauftretens einer komplizierenden Arachnoiditis wird hervorgehaben

We express our gratitude to Dr *Claes Rålberg* Roentgen Department II Sahlgrenska Sjukhuset for his kind advice regarding roentgen interpretation

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THE SPINAL FUSION, OUR TECHNIQUE AND ITS EVALUATION

By

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This report presents our technique of spinal fusion with which we have practised for more than 20 years (developed by F. S.) and the results achieved with it. No originality is claimed but we have failed to find it mentioned in the literature available to us.

Two techniques with its variations are employed for the fusion of the posterior elements of the spine. One consists of the splitting of the spinous process and introduction of a graft (*Albee, Gibson*) or the use of the laminae and the base of the spinous process for grafting (*Young, Henry & Geist, Dobrotworski* a. o.) and the second introduced by *Hibbs* and further developed and modified by others (*Ghormley, Peter, Steindler, Overton*) consists of denuding the laminae using the local bone as graft material and excision of the articular processes. To the denudation of the articular processes internal fixations have been added (*Hadra, Fett, Wilson* a. o.).

The great effort put into a good fusion technique is understandable if one studies the results which give figures of failures in solid fusions from 4.3 per cent in Scoliosis (*Cobb*) to 60 per cent in Spondylolysthesis (*Hammond*).

OUR TECHNIQUE

We use the standard supine position preparing the skin with soap and alcohol and infiltrating the muscles and subcutaneous tissue with a solution of Novocain—(0.25 per cent) with Adrenalin sol. (8 drops of 1/1000 to 100 cc of fluid) in order to render the field bloodless.

Special care is attached to the subperiosteal exposure of the spinous processes. Each process is exposed separately from both sides, the area

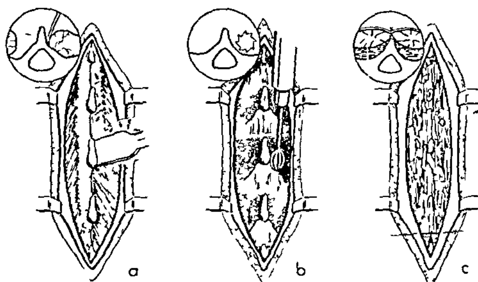


Fig. 1 a–c

packed with a pad soaked in the same solution mentioned above for infiltration. In this way as many processes are exposed as necessary for the planned fusion. In the next step the separated exposures are connected and again the area is solidly packed (Fig. 1a). Here care is also taken to remain in the subperiosteal plane. Then with a 4 cm broad chisel the muscles are pushed to the side as far as over the articular processes. This is done by starting a semicircular movement from the base of the laminae towards the articular process. This is the only phase of the procedure where bleeding can occur and can be secured by tight packing with soaked pads (Fig. 1a). If the fascia of the erector trunci muscles is very tight it is incised freely at the 4 corners of the exposure. This step is mostly necessary in the lumbosacral region.

The denudation of the laminae as far as the articular joints is the next step in the procedure. This step which in very skilled hands takes quite a time can with the help of a ball burr be done in less than a few minutes. The burrs are available in different sizes so that it can be fitted to the width of the laminae. One starts at one end of the field and moving the burr down takes the cortical bone off till spongy bone is visible. The bone dust remains in the place and the area denuded is *lightly packed with soaked sponges. This movement goes down over the* area on both sides of the spinous processes (Fig. 1b). When the surgeon is satisfied with the result the spinous processes are cut off at their bases. In this way the area of spongy bone is enlarged. It is wise to leave

this step till the end in order to control the movement of the burr better. No hammering and chiseling is done and this step has as yet never caused changes in the general condition of the patient. No joints are exposed.

As bone graft we prefer autogenous spongy bone taken from the posterior iliac spine and ilium at the same time of the fusion procedure or from the anterior iliac crest 10 days before. If this is not sufficient we add boiled bone from the bank (Fig. 1c).

In the cervical spine we leave the spinous processes intact, wiring them in addition to the graft. In one case of fract. dislocation at D_1 we used an additional plate.

In Scolioses we place the patient in the corrected position in plaster with a great window in the back; in all other cases our patients are without plasters even after the operation until they can be put on their feet 8–12 weeks after operation. We generally use a Sandwich Bed for the post operative period.

During the past years 68 spinal fusions have been carried out by the senior members of the department. Of these 68 patients two died as a result of the operation. They will be reported in detail but have been excluded from this survey.

The aetiology and region of fusion are shown in Table 1.

TABLE 1
Aetiology and Region

Aetiology region	TB	Fracture	Scoliosis	Instability	Spondylolisthesis	Total
Cervical				3		3
Dorsal	8	3	2	1		14
Dorso-lumbar	10	6	10			26
Lumbar	1	2		1	1	5
Lumbosacral	4	2		6	6	18
Total	3	13	12	11	7	66

Number of fused vertebrae is presented in Table 2.

A total of 342 intervertebral spaces were fused. As was expected the longest fusions were done at the dorsal and dorso-lumbar areas and the shortest ones in the cervical and the lumbo-sacral regions. The most extensive fusions were performed in some of the tuberculous cases and of course in scolioses (Table 3).

TABLE 2
Number of Fused Vertebrae and Region

Number of Vertebrae	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cervical		3											3
Dorsal				4	3	3		2	2				14
Dorsolumbar			3	3	3	1	3	4		5	2	2	26
Lumbar	1	1	2	1									5
Lumbosacral	1	9	5	1	1	1							18
Patients	2	13	10	9	7	5	3	6	2	5	2	2	66
Intervertebral spaces	2	26	30	36	35	30	21	48	18	50	22	24	342

TABLE 3
Number of Fused Vertebrae and Aetiology

Number of Vertebrae	2	3	4	5	6	7	8	9	10	11	12	13	Total
T.B.			3	3	5	3	2	5	2				23
Fracture		1	4	6	1		1						13
Scoliosis						1		1	1	5	2	2	12
Instability	1	8			1	1							11
Spondylolisthesis	1	4	2										7
Patients	2	13	9	9	7	5	3	6	3	5	2	2	66

We included in our studies patients with at least a two years follow up period. The average follow up was 6.4 years (Table 4).

TABLE 4
Years of Follow Up

Years	2	3	4	5	6	7	8	9	10	11	12	Average	6.4
Patients	4	2	10	7	6	6	3	3	5	10	10	Total	66

There have been in this series 7 postoperative infections. Of these 4 infections occurred after autogenous graft material and 3 after homogenous bone material. Of these 7 infections, 5 healed after discharging some of the bone material. In two patients surgical revision was necessary in order to clean the infected areas. 5 of these infections occurred in tuberculous patients.

The roentgenological control of the fused area (Table 6) was done by bendings film and if necessary by tomographic technique. 63 fusions

were soundly healed while 3 demonstrated pseudarthroses (described later in detail)

TABLE 5

Postoperative Infections

	Autograft	Homograft	Patients total
	Infected	Infected	
TB ..	2	3	[illegible]
Fracture ..	0	0	13
Scoliosis ..	0	0	[illegible]
Instability	0	0	11
Spondylolisthesis	2	0	7
			66

TABLE 6

Roentgenological Results of Fusions

	Solid	Pseudarthrosis	Total
Fusions	63	3	66
%	95.5	4.5%	100%

A personal follow up was made on 54 out of 66 patients. We divided these patients in 4 groups

1. Very good no pains normal daily activities no clinical findings
2. Good occasionally pains in the back normal daily activities no clinical findings
3. Fair frequent pains in the back limited daily activities but still no clinical findings
4. Poor constant pains in the back extremely limited daily activities positive clinical findings

According to this classification we had one poor and three fair results (Table 7)

TABLE 7

Clinical Results of Fusion

	Very good	Good	Fair	Poor	Total
Clinical Result	3	18	3	1	[illegible]
	[illegible]		7.4		100

TABLE 2
Number of Fused Vertebrae and Region

Number of Vertebrae	2	3	4	5	6	7	8	9	10	11	12	13	Total
Cervical		3											3
Dorsal				4	3	3		2	2				14
Dorsolumbar			3	3	3	1	3	4		5	2	2	26
Lumbar	1	1	2	1									5
Lumbosacral	1	9	5	1	1	1							18
Patients	2	13	10	9	7	5	3	6	2	5	2	2	66
Intervertebral spaces	2	26	30	36	35	30	21	48	18	50	22	24	342

TABLE 3
Number of Fused Vertebrae and Aetiology

Number of Vertebrae	2	3	4	5	6	7	8	9	10	11	12	13	Total
T.B.			3	3	5	3	2	5	2				23
Fracture		1	4	6	1		1						13
Scoliosis						1		1	1	5	2	2	12
Instability	1	8			1	1							11
Spondylolisthesis	1	4	2										7
Patients	2	13	9	9	7	5	3	6	3	5	2	2	66

We included in our studies patients with at least a two years follow up period. The average follow up was 6.4 years (Table 4).

TABLE 4
Years of Follow Up

Years	2	3	4	5	6	7	8	9	10	11	12	Average	6.4
Patients	4	2	10	7	6	6	3	3	5	10	10	Total	66

There have been in this series 7 postoperative infections. Of these 4 infections occurred after autogenous graft material and 3 after homogenous bone material. Of these 7 infections, 5 healed after discharging some of the bone material. In two patients surgical revision was necessary in order to clean the infected areas. 5 of these infections occurred in tuberculous patients.

The roentgenological control of the fused area (Table 6) was done by bendings film and if necessary by tomographic technique. 63 fusions

electric burr within a few minutes and with no trauma thus strikingly reducing the danger of spinal shock developing as a result of the prolonged hammering The joints are not fused

2 We have operated on 66 patients with an average of six years follow up On average five intervertebral spaces were fused

3 Beside fusion for scoliosis the postoperative care was performed on a turning frame without plaster fixation

4 With this technique we achieved clinically 92 6 per cent good and 7 4 per cent fair and poor results

5 Roentgenologically we had 95 5 per cent solid fusions and 4 5 per cent pseudarthroses

RESUME

1 La technique de fusion vertebrale acceptee consiste a une denudation de l os cortical des elements postérieurs y compris les articulations au moyen d un marteau et d un ciseau intervention qui demande un laps de temps considerable L avantage de notre methode c est de pouvoir accomplir ce processus avec une foreuse electrique dans l espace de quelques minutes et sans trauma en reduisant par consequent beaucoup le danger de choc vertebral par suite de la frappe prolongée du marteau Les articulations ne sont pas fusionnees

2 Nous avons opére 66 malades qui ont ete suivis pendant une periode moyenne de six ans En moyenne cinq espaces intervertebraux ont ete fusionnés

3 A cote de la fusion pour scoliose des soins post opératoires ont été donnes sur un cadre tournant sans fixation dans le platre

4 Avec cette technique nous avons obtenu dans 92 6 pour cent des cas des resultats cliniquement bons et dans 7 4 pour cent des cas des resultats moyens et mauvais

5 Radiographiquement nous avons eu des fusions solides dans 95 5 pour cent des cas et des pseudarthroses dans 4 5 pour cent

ZUSAMMENFASSUNG

1 Die gebrauchliche Technik der Wirbelverschmelzung besteht in der Entblossung des kortikalen Knochens der rückwartigen Bestandteile einschliesslich der Gelenke mittels Hammer und Meissel ein Vorgehen das viel Zeit erfordert Der Vorteil unserer Methode ist dass dieser Schritt mit einem elektrischen Zapfchenbohrer in wenigen Minuten und ohne Trauma ausgefuhrt wird Dadurch wird die Gefahr

des spinalen Schockes der sich infolge des zu langen Hammerns ent wickeln kann deutlich herabgesetzt Die Gelenke werden nicht ver schmolzen

2 Wir haben 66 Patienten mit einer durchschnittlich sechsjahrigen Beobachtungszeit operiert Durchschnittlich wurden funf Zwischen wirbelraume verschmolzen

3 Abgesehen von der Verschmelzung wegen Skoliose wurde die postoperative Pflege auf einem Drehrahmen ohne Gipsfeststellung durchgefuhrt

4 Mit dieser Technik erhielten wir klinisch 92 6 Prozent gute und 7 4 Prozent mittelmassige und schlechte Ergebnisse

5 Rontgenologisch hatten wir 95 5 Prozent solide Verschmelzungen und 4 5 Prozent Pseudarthrosen

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RUPTURE OF THE PECTORALIS MAJOR MUSCLE

A Case Report

By

GEORG BAKALIM

While the biceps muscle tendon shows the highest rate of rupture of all tendons this lesion is very infrequent in the tendon of the pectoralis major According to *Pulaski & Chandler* (1941) the first case was published in 1822 by *Patissier* In this septic infection developed in a haematoma arising in connexion with the damage and the patient died *Borcher & Tonlscheff* (1932) found that only 10 cases had been described by the beginning of this century These authors reported one case of their own and *Pulaski & Chandler* (1941) likewise reported one In addition the latter authors analysed the 19 cases previously published and suggested a classification according to the mechanism of the injury i e 1) exceptionally strong contraction of the muscle 2) a direct blow on the muscle 3) a combination of these two mechanisms In two cases children had performed very heavy work In another two cases there was no history of trauma In these the damage was attributed to marked atrophy of the tissues due to old age *Kingsley* (1946) too reported one case and surveyed the previous literature In his textbook *Bunnel* (1964) describes a case in which the patient had been run over by a lorry and the obvious cause was thus direct trauma *Danielsson* (1964) describes this rupture as a typical lesion in athletes mainly in wrestlers This does not appear to be generally recognized since I have not been able to find any mention of it in the available literature on injuries sustained by athletes My own case belongs to this group

Summarizing the cases described in the literature it may be stated that the majority have been untreated and have later been diagnosed

incidentally. They have exhibited varying degrees of limitation of adduction and inward rotation movements which are performed solely by the pectoralis major. It appears that the rupture mostly did not occur at the insertion into the humerus. Since in many cases the loss of function has not been described as total, it may be assumed that a partial rupture was involved, or that some kind of adhesion with adjacent tissues had formed. Apart from the insertion, the pars clavicularis, sternocostalis and abdominalis may be the site of the rupture.

The present patient was a 24-year-old salesman, who had practised weight lifting for many years. He was of typical athletic build, and in very good condition and had mostly been in good health. He had not regarded himself as fit for top results owing to certain difficulties he had with his foot muscles. When the accident happened, he was lifting 190 kg supine on a bench. For some reason or other, the weight swerved in a way that affected the right arm. He felt a sudden pain high up medially in the arm. People at the other end of the hall heard a dull snap, as when a thick rope breaks in two. Then the patient himself noticed that the right arm could not be moved in the direction of the contralateral shoulder.

The next day, when the patient presented himself at the Outpatients Department, active inward rotation and adduction of the right arm were impossible, while other movements were normal. Passive mobility was intact. No contraction of the pectoralis major was visible or palpable at the anterior axillary fold, which appeared to be softer and limper than that of the unaffected side. On contraction, the sternocostal part of the muscle appeared to bulge forward somewhat, though not conspicuously. A large haematoma extended from the site of the insertion of the pectoralis to the middle of the medial part of the forearm (Fig. 1). A roentgenogram of the shoulder joint showed nothing noteworthy. The soft part shadow appeared to be normal, but the investigation was hampered by the strong development of the musculature.

All signs were indicative of rupture of the pectoralis major. The problem was to decide whether the rupture was partial or total. The site of the haematoma and the tenderness suggested a rupture near the insertion into the humerus. Operation was regarded as indicated, particularly owing to the patient's interest in weight lifting. It was necessary to restore muscular function as completely as possible.

At the operation a longitudinal incision was made along the insertion of the pectoralis major to the humerus. A total rupture of the tendon was revealed in the immediate vicinity of the posterior bicipital

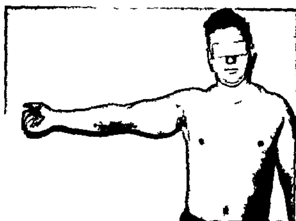


Fig 1

The condition one day after the accident and before operation The outline of the pectoralis muscle at the anterior axillary fold was not so conspicuous as usual and not what might be expected in an athlete A large haematoma had developed which extended as far as the middle of the forearm

ridge The rupture surface was very smooth it looked almost as if it had been incised Distally a remnant of the insertion the size of a finger tip was detected The rupture had occurred practically at the bone surface and the muscle had retracted a few centimetres The problem was to establish a strong reinsertion of the muscle to the bone surface For this purpose two holes were drilled perpendicularly into the posterior bicipital ridge Through each hole two silk sutures were drawn and a further two through the small remaining insertion stump attached to the humerus Thus a total of six strong sutures were applied After the operation the arm was immobilized with an elastic adhesive bandage for three weeks During the first two weeks the arm was kept in adduction with the hand directed towards the contralateral shoulder Exercise was commenced after six weeks After eight weeks the joint had regained normal mobility in all directions Later it was found that the patient had secretly taken up weight lifting as early as eight weeks after the operation Obviously this had no untoward effects Three months after the operation he reported that he had been able to lift 100 kg The arm was practically painless By then he had not yet resumed supine exercises however and in general he had tried not to strain the operated arm unduly The observation time is now two years (Fig 2) Muscular function is completely restored and the mobility of the shoulder joint is normal

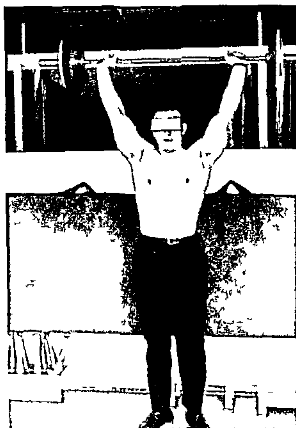


Fig 2

The patient is seen lifting 0 kg three months after the operation In fact he had by then already lifted 100 kg

DISCUSSION

The majority of cases described in the literature have been conservatively treated They have not come under treatment until a long time after the lesion was sustained and many have been diagnosed incidentally The result has been limitation of function varying in degree In the present case the rupture was total Spontaneous restitution of muscular function seemed very improbable

Rupture of the pectoralis major muscle has previously been regarded as very infrequent In its more or less partial form it does perhaps occur in athletes more often than has been presumed Total rupture must still be considered a rarity however Obviously the symptoms

may be very pronounced In uncertain cases an exploratory operation which is a minor procedure may be indicated It is readily understandable that a lesion of this kind is a great handicap to certain athletes in particular wrestlers boxers and weight lifters

SUMMARY

A case of total rupture of the pectoralis major muscle is described The patient was a 24 year old salesman who had sustained his lesion during weight lifting supine on a bench The weight of the bar bell was 190 kg Inward rotation and adduction of the arm was rendered impossible A haematoma developed from the site of the rupture as far as the middle of the forearm The patient was operated on without delay Total rupture had occurred immediately at the insertion of the muscle into the posterior bicipital ridge The muscle was attached to the bone by sutures drawn through holes drilled through the humerus Complete function was restored After eight weeks the patient had resumed weight lifting

Rupture of the pectoralis major muscle has been regarded as very infrequent Only a few cases have been described The majority have come under treatment very late or been diagnosed incidentally In untreated cases a *limitation of function varying in degree results*

RESUME

Un cas de rupture totale du muscle grand pectoral est décrit Le malade etait un vendeur age de 24 ans chez lequel la lesion s etait produite au levage d un poids en position couchée sur un banc Le poids de la barre de cloche etait de 190 kg La rotation en dedans et l adduction du bras avaient ete rendues impossibles Un hematome s est développe du cote de la rupture jusqu au milieu de l avant bras Le malade fut opere sans delai La rupture totale s est produite a l endroit de l insertion du muscle dans la gouttiere bicipitale postérieure Le muscle a ete attache a l os par sutures tirees par des trous perfores a travers l humerus Une fonction complete a ete restauree Au bout de 8 semaines le malade etait a nouveau capable de soulever un poids

La rupture du muscle grand pectoral a été consideree comme tres rare Quelques cas seulement ont ete decrits La majorite des cas ont ete mis en traitement tres tardivement ou ont éte diagnostiques incidemment Dans les cas qui ne sont pas mis en traitement une reduction de la fonction a des degres variables en resulte

ZUSAMMENFASSUNG

Ein Fall von vollständiger Zerreissung des m pectoralis major wird beschrieben Der Patient war ein 24 Jahre alter Verkaufer der diese Verletzung erlitt während er auf einer Bank lag und ein Gewicht hob Das Gewicht der Barglocke war 190 kg Einwärtsdrehung und Adduktion des Armes war unmoglich Ein Haematom entwickelte sich von der Rupturstelle bis zur Mitte des Unterarmes Der Patient wurde sofort operiert Vollstandige Ruptur war direkt an der Insertion des Muskels in der Crista tuberculi majoris entstanden Der Muskel wurde mittels Suturen befestigt die durch Bohrkanale im Humerus gefuhrt wurden Vollstandige Funktion wurde wiederhergestellt Nach acht Wochen hat der Patient das Gewichtstemmen wieder aufgenommen

Ruptur des m pectoralis major ist als ein sehr seltenes Ereignis angesehen worden Nur wenige Falle sind beschrieben worden Die Mehrzahl davon ist sehr spat zur Behandlung gekommen oder wurde nur zufällig diagnostiziert In unbehandelten Fällen bleibt eine verschiedengradige Einschränkung der Funktion zuruck

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DETERMINATION OF HIP ADDUCTION, ESPECIALLY IN ARTHRODESIS

By

Olov Lindahl

It is usual to consider the frontal mobility of the hip joint (abduction and adduction) in the sagittal position of the hip that is obtained when the patient is lying supine on a plane table it is this mobility that was examined in this study In most text books and articles in which this mobility is dealt with it is stated that the measurement shall be made from a zero position in which the leg forms a right angle with a line between the anterior superior iliac spines Values given for the movement from this zero position range from 25 to 45 abduction and from 10 to 35 adduction (2 3 5 7 14 16) Fick (6) gives 46 and 28 respectively

These wide variations in what is considered normal suggest that there is some inexactness in the methods of examination Perkins (13) considers that adduction in particular cannot be measured accurately in degrees and he does not give any magnitude for it The shortcomings of the method of measurement are probably due in part to the difficulty in palpating and locating the exact site of the iliac spines and to the fact that the axis of the leg is not well defined It is extremely difficult for one person simultaneously to manipulate an angle measuring device adduct the leg and palpate the two spines This method provides only a rough impression of the range of movement for the extent to which the pelvis also moves is difficult to judge When a hip arthrodesis has been performed the measurement is still more difficult because the spine is often involved in the scar tissue and is not infrequently used as graft material Since in hip arthrodesis a small change in the frontal plane has a considerable effect on the length of leg and the position of the pelvis and spinal column (an adduction of 3 shortens the leg by about one centimetre) the inaccuracy of the method is a

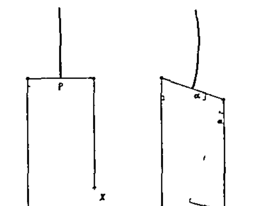


Fig 1

The relationship between the shortening of the leg and angle needed to compensate for the shortening

The feet are the same distance apart as the centres of the femoral heads

serious disadvantage The problem has been noted by several authors (1 8 10 11 15) in respect of hip arthrodesis and subtrochanteric osteotomy and tables have been compiled for the determination of the number of degrees of abduction required to correct for a given shortening of legs of different lengths and for different distances between the iliac spines or centres of the femoral heads *Milch* (12) has designed a special appliance to natural size by means of which any required angle and change in length of leg can be set and measured (adduction osteotometer) Accurate tables for determining the angle are however of little value when the practical difficulties in measuring the angle on the patient remain

This problem has assumed practical significance in a follow up examination of patients with hip arthrodesis and the author has developed a method for determining adduction and in some cases abduction to an accuracy of about 3

Briefly the method consists in measuring the distance between the medial malleoli with the leg in maximum adduction the measurement is made in the axial direction of the leg and with the feet together The adduction is then obtained in terms of a distance When there is a real shortening the adduction is obtained by subtracting this from the intermalleolar distance

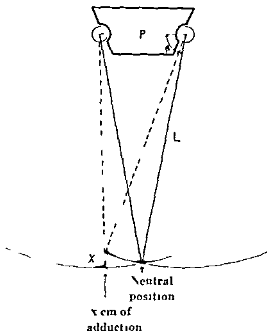


Fig 2

The relationship between the shortening of the leg and the angle of the leg to the line joining the femoral heads The feet are together

MECHANICS OF THE FRONTAL MOBILITY

Most diagrams relating to the frontal mobility of the hip joint are similar to that in Fig 1 It is seen here that the extent to which the leg length is affected by a change in angle between the leg and the pelvis is dependent on the distance between the centres of the femoral heads (P) The angular deviation (α) corresponding to a shortening (X) is given by the expression $\sin \alpha = X/P$ This presupposes a normal position of the hip with a right angle between the leg and the two spines which implies that the leg length is determined in the usual zero position with the feet about 20 cm apart but this is quite an unnatural position whether standing or walking With the feet together the difference in leg length is given by a different mathematical relationship Fig 2 shows a model of the relationship between leg length and the position of the hips in the frontal plane For a certain angle of one hip the shortening of the leg with the feet together is given *by the following formula*

$$X = L - (L^2 + P^2 - 2LP\cos\beta)^{\frac{1}{2}}$$

or

$$\cos\beta = \frac{P^2 + 2LX - X^2}{2LP}$$

where L = the leg length P the distance between the centres of the femoral heads X the shortening of the leg due to adduction β the angle between a horizontal line through the pelvis and the line through the centre of the femoral head and the medial malleolus

The longitudinal axis of the leg is not accurately enough defined for an exact measurement of the angle of adduction In this study the longitudinal axis is taken as the line from the centre of motion of the femoral head to the tip of the medial malleolus The centre of the head corresponds quite closely on the skin to the intersection of the inguinal ligament and the femoral artery This axis does not coincide with the various clinical axes that can be obtained in the outer contour of the thigh nor with the radiographic axis through the femur which does not pass through the centre of motion (Fig 3) Instead of the zero position with the feet about 20 cm apart and a right angle between the legs and the horizontal I have chosen a more natural basic position with the feet together This is referred to below as the *neutral position*

TABLE 1

The Neutral Angle for Different Lengths of the Legs and Distance between the Centres of the Femoral Heads

Distance between femoral heads (cm)	Neutral angle for length of legs (cm) 80	85	90	95	100	105	110
19	83.2	83.6	83.9	84.3	84.5	84.8	85.0
20	82.8	83.2	83.6	84.0	84.3	84.5	84.8
21	82.5	82.9	83.3	83.7	84.0	84.3	84.5
22	82.1	82.4	83.0	83.4	83.7	84.0	84.3
23	81.7	82.2	82.7	83.0	83.4	83.7	84.0
24	81.4	81.9	82.3	82.7	83.1	83.4	83.7
25	81.0	81.5	82.0	82.4	82.8	83.2	83.5

The neutral angle δ is given by the expression $\cos\delta = B/2L$ where B is the distance between the centres of the femoral heads and L is the length of the leg

In the neutral position the angle between the legs and pelvis will vary with the distance between the two centres of the femoral heads and with the leg length (Table 1) According to the former nomenclature there is in this neutral position an adduction of between 5 and

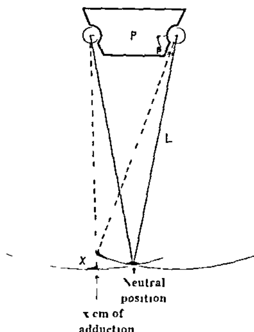


Fig 2

The relationship between the shortening of the leg and the angle of the leg to the line joining the femoral heads The feet are together

MECHANICS OF THE FRONTAL MOBILITY

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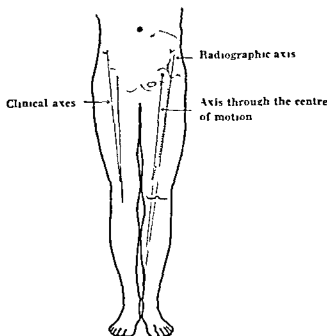


Fig 3
Various longitudinal axes of the leg

There may be certain objections to this subtraction from the theoretical standpoint because a real shortening of one centimetre in the neutral position gives an intermalleolar distance of slightly more than one centimetre This small difference is however of no practical significance The same applies to errors that arise through migration of the acetabulum in the medial as well as the cranial direction

RADIOGRAPHIC EXAMINATION OF FRONTAL MOBILITY AND POSITION

Though measurement of the range of movement of the hip-joint in the frontal plane by means of radiographs in two extreme positions is simple from the theoretical standpoint this method would seem to have been little used An adduction *position* in the hip-joint can also be determined on radiographs but the long axis of the leg through the head of the femur cannot be found unless a radiograph of the whole leg is obtained The "clinical" axis in the centre of the thigh contour is not visualized and the axis obtained from the femur does not pass through the centre of motion (Fig 3)



Fig 4

Radiograph of the pelvis and femurs from a patient with left sided hip arthrodesis DE–BF is the real shortening and γ the angle between the radiographic axis of femur and a horizontal line through the pelvis

In 24 cases in which arthrodesis had been executed in the hip and in which the adduction position was examined by radiography a frontal view was taken of the pelvis and the upper part of the thigh with a focal distance of 100 cm and with the central ray midway between the hips On these radiographs a 10 per cent enlargement was assumed and this was usually in agreement with the true distance between the skeleton and the film in relation to the focal distance On the radiographs a horizontal reference line was drawn usually between the lower range of the two sacro iliac joints (Fig 4) The angle between this line and a line through the cortical contour of the femoral shaft was determined This line usually passes in a direction towards the medial malleolus (Fig 3) The distance between the intersection of the two lines (A) and a point midway between the hip joints (C) was measured (10 per cent reduction owing to the enlargement) On the

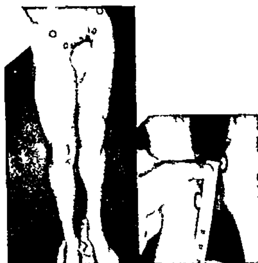


Fig 5

Technique for measuring the adduction in terms of the intermalleolar distance

basis of the length of the normal leg and the distance A C the neutral angle of the normal side was calculated. The difference between this and the adduction angle on the rigid side was taken as a measure of the adduction in the rigid hip. In the determination of the extent of the adduction and the position of the leg on the radiographs several measurements and estimates must be performed, and it can therefore never be completely accurate. The determination of the angle between the femur and the horizontal line through the pelvis can, of course, be exact, but this does not give any impression of the adduction of the hip in relation to the zero or neutral position.

The real shortening in the hip joint on the side of the arthrodesis was measured by subtracting the distance on both sides between the horizontal reference line and the tip of the lesser trochanter (Fig 4 DI, BF).

A NEW CLINICAL METHOD FOR DETERMINING THE ADDUCTION IN THE HIP JOINT

The method can be used for one or two mobile hips but it is necessary for the *ad*duction of the hip under examination to be less than the *ab*duction of the other hip, as is normally the case, and usually is the case when it is desired to determine the adduction of a diseased hip. However, both legs must be the same length or any real shorten-

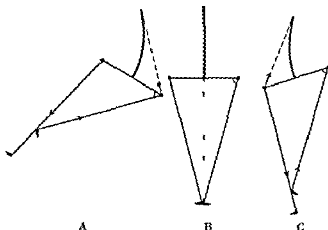


Fig 6

Diagram of the legs hips and spinal column (B) in the neutral position (A) in an oblique suitable for measurement of adduction and (C) with the legs in the long axis of the body a position unsuitable for the measurement of adduction.

ing must have been determined radiographically The extent of the adduction as the actual adduction position is measured as the intermalleolar distance The use of the medial malleolus as the reference point instead of the inferior surface of the heel involves a small approximation which may be of clinical significance if there should be a considerable difference in size between the heels To facilitate the measurement between the malleoli these should first be palpated and the tips marked on the skin The hip under examination is then adducted by moving the leg in the direction of adduction axial pressure is applied to it while traction is applied to the other leg The legs are held close together throughout (Fig 5) So as to be able to obtain full adduction it is important for the two legs to be taken to the side so that the back is also bent and the pelvis is held firm by stretching the muscles between the back and the pelvis (Fig 6 A) If only pressure is applied to the leg to be adducted and tension is applied to the other adduction may be prevented through a too small mobility of the back and in this position there is also a much greater elastic resistance to the adduction movement (Fig 6 C) The intermalleolar distance with the feet together is measured If the legs are the same length this measurement is the adduction of the leg under examination (for instance left hip adduction —4 cm) If there is a true shortening of the leg of the examined side this (*e g* 2 cm) is subtracted from the intermalleolar distance (*e g* 7 cm) and the remainder (5 cm) is then



Fig 7
Measurement of the position of the left hip on the operation table in the frontal plane when a nail arthrodesis is about to be performed

the measure of the adduction (—5 cm) In cases in which arthrodesis of the hip has been performed the intermalleolar distance is measured with the legs together and the real shortening is subtracted The remainder constitutes the adduction position (*e g* left hip rigid with an adduction of —3 cm)

If there is an *ab*duction position that is so moderate that the mobile leg can still be taken to the rigid one the value will be positive (*e g* left hip rigid with abduction position of +4 cm) Here too the distance between the malleoli (*e g* 2 cm) is measured but in this case any true shortening (*e g* 2 cm) is added to give the abduction (+4 cm) In a determination of the magnitude of a contracture position the procedure is in principle the same If there is an adduction contracture an attempt is made first to correct it so far as possible by pressing in the axial direction on the sound leg and applying traction to the contracted one If there is still a distance between the malleoli (*e g*

2 cm) and the leg with an adduction contracture is still short there is an adduction contracture of —2 cm All these distances can be converted to angles either roughly by multiplying by 3 or more accurately by using the above formula but in practice the distance value is more useful since this corresponds to the shortening that the patient experiences when walking and standing or the shortening that must be compensated for by surgery or other means

If in a case of hip arthrodesis it is necessary to set the leg in a certain position on the operation table the following reasoning may be used Suppose that there is a true shortening of one centimetre through migration of the acetabulum, measured on radiographs No further shortening is expected to result from operation and healing It is desired to compensate for the shortening entirely by abduction so that legs are the same length when walking and standing According to the above reasoning the hip under examination must be set in such a position that the two malleoli are at the same level when they are held together On the operation table it is, however difficult or impossible to hold the legs together and it is therefore necessary to set the hip and then to measure with a tape (i) the distance from the centre of the mobile hip (the intersection between the inguinal ligament and the femoral artery) to the medial malleolus of the same leg and (ii) the distance from the same centre to the malleolus of the leg to be operated on These distances should then be equal (Fig 7)

TABLE 3

Adduction Position for 24 Subjects for whom Hip Arthrodesis was Performed Measurements Performed Clinically (C) and on Radiographs (R) Values in mm

C	R	C	R	C	R	C	R	C	R	C	R
—14	−20	4	0	+12	+20	—47	—40	+10	0	+10	0
0	[illegible]	—32	—40	+12	+10	+ 8	0	− 15	—15	− 31	−40
− 12	25	—32	−45	+36	+45	—70	70	−17	—30	—23	−30
+12	0	+ 3	+ 5	+22	+30	+21	+20	—18	—15	0	[illegible]

COMPARISON BETWEEN RADIOGRAPHIC AND CLINICAL MEASUREMENTS

In 24 patients for whom a hip arthrodesis had been performed the adduction from the neutral position was measured on radiographs and by the new clinical method The agreement between the two methods was fairly close for there was a deviation of more than one

centimetre (corresponding to 3°) in only 4 of the subjects (Table 3). In view of the unreliability of the numerous measurements on the radiographs there is reason to believe that the clinical method is the more accurate.

TABLE 4

Adduction versus Age Measured by the Proposed Clinical Method

Age	20–29	30–39	40–49	50–59	60–69	70–79	Cases of osteoarthritis
No. of subjects	10	9	8	9	7	7	20
Mean adduction (cm)	−10.2	−9.4	−8.8	−6.1	−6.1	−3.4	−2.9
Range (cm)	8–14	6–12	5–13	2–10	1–8	0–7	0–5

VARIATION OF THE ADDUCTION WITH AGE

By means of the new clinical method a study of adduction was performed on a series of subjects with clinically sound hips (50 cases) and on 20 patients with osteoarthritis. The former were examined for other complaints not involving the hips and none had had symptoms from the hips; usually they had not undergone radiologic examination. It was found that the adduction capacity of the sound hips decreased with age and was low for subjects with osteoarthritis (Table 4). Quite large individual variations were found. Adduction contracture was of course common among the cases of osteoarthritis, and the magnitude of this contracture could be obtained accurately by this method.

DISCUSSION

It is of course difficult to change the time honoured clinical methods of measurement, and this is especially true of adduction of the hip, which in most respects is not of major clinical interest. Since, however, this range of movement is entered in practically all record sheets at orthopaedic clinics and expressed as an angle, and since the value is obviously quite arbitrary, this form of measurement should logically be abandoned when it is not required and should be made more accurately in the cases where it is of real interest. The method presented above would probably meet the usual requirements of accuracy and is moreover simple to use. Its greatest value is perhaps for setting the hip on the operating table when a nail arthrodesis is being planned.

In a series of 35 follow up cases with hip arthrodeses[9] the adduction ranged from —3 3 to +6 4 cm (positive values indicate abduction) and the intermalleolar distance (without correction for the true shortening) from —7 0 to +4 5 These values reflect the difficulty in setting the joint in the right position for an arthrodesis though of course there were other factors too that contributed to this large range

SUMMARY

The usual clinical measurement of the frontal mobility of the hip is discussed and criticized On the basis of the mathematical relationship between the shortening of the leg and adduction a new clinical method is presented for determining the adduction of the hip in which the distance between the medial malleoli is measured in the axial direction of the leg with the feet together In this way a measure can be obtained of the true adduction position and of the total adduction in the latter case the measurement is performed on the fully adducted hip The method is more accurate than others and indicates directly the dependence of the length of the leg on the adduction especially in connection with hip arthrodesis

RESUME

La mensuration clinique usuelle de la mobilite frontale de la hanche est discutee et critiquee sur la base d un rapport mathematique entre le raccourcissement de la jambe et l adduction Une nouvelle methode clinique est presentée pour déterminer l adduction de la hanche en mesurant la distance entre les malleoles medianes en direction axiale de la jambe les deux pieds joints De cette maniere on peut obtenir une mesure en vraie position d adduction et en adduction totale Dans le dernier cas la mensuration est effectuee sur la jambe entièrement en position d adduction La methode est plus exacte que d autres et indique directement la dependance de la longueur de la jambe par rapport a l adduction en particulier en relation avec l arthrodèse de la hanche

ZUSAMMENFASSUNG

Die gewohnliche klinische Messung der frontalen Beweglichkeit der Hufte wird besprochen und kritisiert Auf Grund der mathematischen Beziehung zwischen Beinverkurzung und Adduktion wird eine neue klinische Methode zur Bestimmung der Huftadduktion vorgestellt

bei der die Distanz zwischen den medialen Malleolen in der axialen Richtung des Beines bei zusammengelegten Fussen gemessen wird In dieser Weise kann man eine Messung der wirklichen Adduktionsstellung und der totalen Adduktion erhalten Im letzteren Falle wird die Messung bei vollständig adduzierter Hufte vorgenommen Die Methode ist genauer als andere Methoden und zeigt die Abhängigkeit der Beinlange von der Adduktion direkt auf besonders im Zusammenhang mit einer Huftarthrodese

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CONGENITAL SHORT FEMUR

By

G Fock and M Sulamaa

In 1936 *Peabody* had collected from the literature 102 cases in which the femurs were congenitally of different lengths Thus this deformity was comparatively rare until 1958 since when the frequency has clearly increased along with other deformities of the extremities caused by thalidomide The problem of the cause of a congenital hypoplastic deformed or partly missing femur its prognosis and possibilities for treatment are still largely unsolved Of course the limp resulting from the difference in length of the extremities can be effectively treated with an orthopaedic shoe so that in childhood the defect is not very disturbing According to *Gylding* (1948) various deformities of the femur cannot be clearly distinguished from congenital coxa vara

The series of deformities of the long bones of the extremities collected from the Helsinki Children s Hospital (*Sulamaa & Ryoppy* 1963) shows that the frequency of such deformities has increased many times since 1957 There was a total of 12 cases treated for difference in length of the femur These slight deformities were not included in our earlier published series Eight of these 12 cases were born after 1957

The aim of the present study of these 12 cases has been to investigate the growth capacity of a congenitally short femur and the effect of treatment on its growth

MATERIAL

The patients were admitted during the period 1957 1963 and with the exception of two cases were under one year old

On the basis of the shape of the femur our cases can be divided into three main groups

1 Cases in which the shape of the short femur was more or less normal There were 6 such cases of *hypoplasia*
2 Cases in which the diaphysis of the short femur of almost normal shape was bent There were 3 such cases of *hypoplasia and varus*



Fig 1

Case 2 Radiograms taken at the age of 4 mo 14 mo and 4 yrs The right femur is of normal configuration but slightly shorter than the left femur which is normal

3 *Partial defect* or pseudoarthrosis of the upper end of the femur 3 cases

One of the patients of the fir t group had other typical thalidomide deformitie " as well *i.e* defect of the ulna In all patients of the hypoplasia group at the initial stage of treatment the periosteum was detached and steel screws introduced into th bone close to the epiphyseal line on both the lower en l of the femur and the upper end of the tibia

In cases of the second group the varus p iti n was correcte l by osteotomy and in four cases including all ca es of group three bone tran plantations of some type were carried out in a ldition

With the aid of radiograms taken at regular intervals at follow up the growth of the femur was foll w e l the femur of the intact si le acting as contr l The pictures were taken at a distance of 1 metre and the length was measured on the films Al though the metho l of measurement is n t exact it till does pr vide when the healthy femur is ra li graphed in the same way a clearly more reliable result than measurement of the extremit itself The perio l of observation ranges from one t six years The difference in length i expresse l l th in cm and as the proportional length of the shorter femur relative to the healthy one Table 1 gives information on our cases

DISCUSSION

The majority of the cases 6 were referred to the hypoplasia group In case 6 there were other typical "thalidomide deformities as well Since there is in the present series a case in which there was aplasia of ulna on one side it seems evident that the hypoplasia of the femur and the other simult ineous bone defect h is a common cause The cases in which the upper end of the femur is partly missing or deformed (cases 10 11 and 12) are very similar to the cases of thalidomide de

TABLE 1

Case	Born	Age of patient at beginning and end of treatment		Operations and age when performed		Difference in length at beginning		Difference in length at end		Type of deformation
						cm	%	cm	%	
1	1961	10 mo	22 mo	Screw	10 mo	3 3	80	3 3	84	Hypoplasia
2	1959	4 mo	45 mo	Screw	4 mo	2 0	94	3 7	87	Hypoplasia
				Screw	31 mo					
3	1955	57 mo	79 mo	Screw	57 mo	1 6	94	2 5	[illegible]	Hypoplasia
4	1958	17 mo	65 mo	Screw	20 mo	2 3	89	3 8	88	Hypoplasia
				Screw	32 mo					
5	1957	[illegible] mo	25 mo	Screw	21 mo	2 2	78	5 4	89	Hypoplasia
6	1960	8 mo	36 mo	Screw	9 mo	[illegible] 5	80	3 8	[illegible]	Hypoplasia and defect of ulna
7	1953	1 mo	60 mo	Osteotomy	1 mo	2 [illegible]	77	5 6	81	Hypoplasia and varus
				Screw	9 mo					
				Screw	18 mo					
8	1958	6 mo	69 mo	Osteotomy	12 mo	4 8	65	4 5	84	Hypoplasia and varus
9	1953	1 mo	75 mo	Screw	12 mo	3 2	6[illegible]	8 0	70	Hypoplasia and varus
10	1961	[illegible] mo	36 mo	Bonegraft	6 mo	8 0	30	12 7	34	Partial defect and defect of fibula and radius
				Bonegraft	12 mo					
11	195[illegible]	5 mo	75 mo	Bonegraft	5 mo	8 7	39	10 7	57	Partial defect and pseudoarthrosis
				Screw	40 mo					
12	1958	2 mo	67 mo	Bonegraft	4 mo	6 5	35	17 9	42	Partial defect and pseudoarthrosis
				Osteotomy	17 mo					
				Bonegraft	3 mo					



Fig 2

Case 7 Radiograms taken at the age of 1 mo 2 yrs 3 mo and 4 yrs 8 mo In the neck of the femur there is a slight bend and moreover the whole femur is bent

fects in our previous series In these cases the difference in length was as a rule considerable Some of the cases of less deformed bent femurs (cases 7 and 8) also resemble in type many deformities caused by thalidomide in other bones Although a thalidomide aetiology is not with certainty demonstrable in any of the present cases the time of occurrence of the majority of these cases argues in favour of such a possibility



Fig 3

Case 10 Radiograms taken at the age of 8 mo and 2 yrs As a result of two bone graft operations the defective right femur has grown to some extent



Fig. 4.

Case 12. Radiograms taken at the age of 2 mo., 2 yrs. 10 mo. and 5 yrs. 7 mo. The markedly defective right femur has grown fairly well, thanks to two bone graft operations and one osteotomy.

The shortening of the femur as measured on the radiogram is best illustrated when the length is reckoned as a percentage of the length of the healthy femur. At the beginning of treatment it varied from 80 to 94 in the hypoplasia group. The relative lengths of the varus shaped femurs ranged between 62 and 77 per cent. A defect of the upper end of the femur (cases 10, 11 and 12) caused a marked shortening. In all cases the shortening was already over 2 cm in infants, with the exception of case 3, in which it was less. The largest difference in length, 8.7 cm, in an infant aged 5 months, was due to a defect in the upper end of the femur.

The follow up period, counted from the beginning of treatment, ranged from 12 to 74 months. In all cases growth led to an increase in the absolute difference in length as compared with the contralateral femur, although the relative difference either remained as before or changed for the better. Detachment of the periosteum and introduction of steel screws does not seem to have stimulated growth to any significant degree. Neither does this small interference seem to have had any negative effect. *Vordentoft & Guldhammar* (1964) came to the same conclusion. A clearly favourable effect on the difference in length was obtained with operative straightening of the varus shaped femur. A favourable effect on the difference in length by transplantation of bone or epiphyseal cartilage was clearly demonstrable in one case only (case 11). In Peabody's cases the difference in length increased as the pa

tients grew older His patients were not operated on He does not state the difference in length in per cent

As compared with the results obtained by Pease in sequelae of polio the results obtained with separation of the periosteum and screws were unimpressive in our cases When the difference in length was not marked the slight limp was easily corrected with an orthopaedic shoe so that the disability did not as a rule cause difficulties of adaptation At the final stage of growth the difference in length may also be reduced by stapling or shortening of the longer limb

Not even a considerable difference in length such as in our cases 10 11 and 12 is so disabling as to be an indication for amputation and a prosthesis as suggested by Blount These patients have learnt to walk well with the aid of a Thomas splint and moreover a prosthesis can be attached to the short limb just as well as to an amputation stump During the few first years of growth an epiphyseal transplant capable of growth may perhaps improve the situation as shown by Ryoppy in his animal experiments

SUMMARY

Twelve cases of congenital unilateral hypoplasia of the femur in children are reported All the patients came for treatment to the Children s Clinic in Helsinki at an early age The material consists of 6 cases of hypoplasia 3 cases of "congenital coxa vara and 3 cases of partial defect of the upper end of the femur In some cases improvement was obtained by osteotomy and bone graft-operations The difference in length usually increases in cm but remains the same in percentage compared with the other side In our opinion there is no indication to perform amputation in early childhood in these cases

RÉSUMÉ

Douze cas d hypoplasie unilatérale congénitale du fémur chez les enfants décrits Tous les malades ont été en traitement en bas âge à la Clinique de Pédiatrie d Helsinki Le matériel d observation comporte 6 cas d hypoplasie 3 cas de coxa vara congénital et 3 cas de défectuosité partielle dans la partie supérieure du fémur Dans certains cas une amélioration a été obtenue par ostéotomie et opération de greffe osseuse La différence de longueur augmente généralement en cm mais

reste proportionnellement la meme par rapport a l autre cote A notre avis il n y a aucune indication pour pratiquer des amputations en bas age dans ces cas

ZUSAMMENFASSUNG

Zwölf Fälle von einseitiger Hypoplasie des Femurs von Kindern werden berichtet Alle Patienten kamen zur Behandlng an die Kinderklinik in Helsinki in einem fruhen Alter Das Material besteht aus 6 Fällen von Hypoplasie 3 Fällen von kongenitaler coxa vara und 3 Fällen von teilweisem Defekt des oberen Femurendes In einigen Fällen wurde eine Besserung durch Osteotomie und Knochenuberpflanzung erreicht Die Längendifferenz nimmt in cm gemessen gewöhnlich zu verbleibt jedoch perzentuell die gleiche im Verhältnis zur anderen Seite Wir haben die Auffassung dass keine Anzeige zur Amputation *im frühen Kindesalter besteht*

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CONGENITAL COMPLETE DISLOCATION OF PATELLA CAUSING SERIOUS DISABILITY IN CHILDHOOD
THE OPERATIVE TREATMENT

By

Henrik Støren[1]

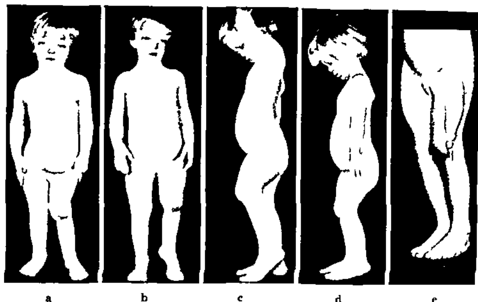
While the congenital predisposition to recurrent dislocation of the patella in its various forms has been dealt with quite extensively in the literature (*De Palma* 1954 *Kapel* 1936) the author has been unable to find any description of the complete congenital irreducible dislocation of patella as an ailment *per se* since that of *Mouchet & Durand* (1921)

However the condition may well be more common than formerly believed and may possibly be the underlying cause in some cases of permanent total dislocation of patella in adults because the malformation for years may give rise to very few symptoms and thus escape diagnosis during childhood At a later stage secondary arthrosis may develop in the knee but is inconstant Cases are known where the patient with a total dislocation of patella has not been bothered by the disorder throughout a long span of life

As in cases of congenital complete dislocation of patella which have been reported earlier the disorder was also seen in the two present cases together with other congenital abnormalities But here the progressive disability caused by the patellar dislocation completely dominated the clinical picture The author was unable to find any description of the characteristic clinical findings in similar cases The rarity of such cases prevents the presentation of a larger number of cases

Case 1 Marit [illegible] born 19[illegible]6 girl was admitted to the hospital at the age of five She had an osteotomy performed on both femurs (probably a rotation osteotomy) in another hospital at the age of one year The osteotomies had united in some varus

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a b c d e

Fig 1

Marit L before operation Demonstrates the typical clinical findings Flexion contracture valgus of the knee outward rotation of the leg Apparent but no real shortening of the limb The foot kept in equinus when walking To the right the laterally dislocated extensor apparatus with the patella has been drawn on the skin

position Roentgenologically and clinically both hips were normal She had several congenital malformations (a non syphilitic saddle neck nose and moderate mal formations of the external genitals) The actual disorder was located in the left lower limb She displayed a marked limp on this side walking with the left foot in equinus which was caused by a 45 flexion contracture of the knee From this position she could only bend the knee another 10 (Fig 1) There was no real shortening of the limb only a relative shortening due to the flexion contracture and she lowered the left iliac spine when walking In order to elevate the iliac spine to a normal level she increased the plantar flexion of the foot accordingly When asked to bring the heel to the ground she did this by flexion of the other knee In addition a 20 valgus was found in the knee with some outward rotation of the leg These factors made walking extremely difficult and deformed her posture (Fig 1) The underlying cause of this flexion contracture of the knee was found to be a complete lateral dislocation of the patella (Figs 2 A–B) The lateral patellar position of patella with the quadriceps muscle and the infra patellar ligament are drawn in the right photographic picture in Fig 1 As may be seen the extensor apparatus of the knee has no possibility of normal function

Case 2 Berit D born 1953 girl had arthrogryposis multiplex with pathological changes of both hips and right sided club foot Her club foot had earlier been treated elsewhere and she was admitted to the Coast Hospital for treatment of a relapse which was done by operation Upon control examination it was noted that she





Fig 2 *b* Marit L Roentgenogram of left knee before operation tangential view patella in its lateral position

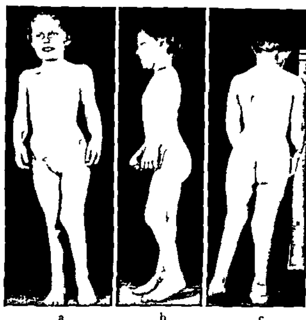
Fig 2 *a.* Marit L Roentgenogram of left knee before operation patella lateral to the lateral femoral condyle A wide gap is seen in the medial inter articular space resulting from valgus deviation of the leg Fibula projected behind tibia demonstrates outward rotation of the leg

walked with her left knee in flexion and in valgus and with some outward rotation of the leg She also kept her foot in equinus contracture or other pathological changes of this foot (Fig 3) A closer examination of the knee disclosed a flexion contracture of 10 a valgus of 30 and an outward rotation of the leg The clinical picture was analogous to that seen in the first case and the cause was found to be the same a total dislocation of patella which could be felt at the lateral aspect of the lateral femoral condyle This finding was confirmed by the roentgenogram which also gives an explanation of the pronounced valgus of the knee a marked gap in the medial part of the joint (Fig 4 and 5)

TREATMENT

As the operation in these cases is more complicated than in even the more severe cases of irreducible patellar dislocation of the common type the technique will because of that be described in detail

The operation was performed in two stages



a b c

Fig 3

Berit D before operation the same typical clinical picture as in the first patient Flexion contracture and valgus of the knee outward rotation of the leg compensatory equinus of the foot when walking

I stage Correction of the flexion contracture through an ordinary bayonet incision in the popliteal fossa all flexor tendons of the thigh were lengthered together with incision of the posterior fibrous capsule In the first case where the flexion contracture was most marked it became necessary also to loosen the femoral origin of the gastrocnemical heads to achieve full correction After the operation a plaster cast was worn for six weeks the first four weeks with the knee in slight flexion to avoid injury to nerves and vessels by too strong tension The last two weeks the patient was allowed to walk about with a plaster cast with the knee in full extension During the following six weeks no plaster cast was worn and active exercises of the knee were performed

II stage Twelve weeks after the first operation transposition of the extensor apparatus (Figs 6 A B) This procedure necessitated a rather radical technique A modified Krogius operation was combined with moving of the tibial tuberosity in medial direction The rectus muscle had to be dissected free in a proximal direction to a considerably larger extent than in the usual Krogius operation in order to place the muscle in a straight line with the patella after this had come into a *normal*

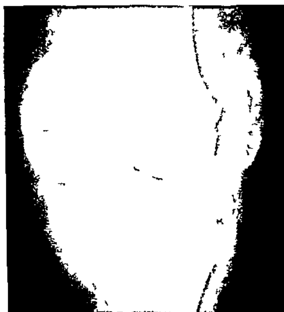


Fig 4

Marit D Roentgenogram of left knee before operation The picture similar to that of the first case Note the wide gap in the medial part of the joint due to the valgus of the knee Outward rotation of the leg Patella is laminated

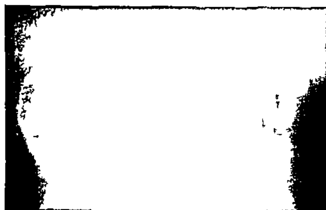


Fig 5

Berit D roentgenogram of left knee before operation tangential view note extreme lateral almost dorsal dislocation of patella

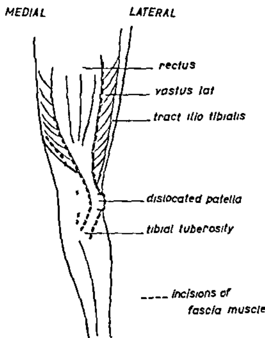


Fig 6 a

Diagram showing the situation before operation Dotted lines incisions in fascia and muscles to free the rectus with tha patella and to prepare a medial flap to be transposed to cover defect on lateral side (see Fig 6 b)

position To obtain this normal position of patella the tibial tuberosity had to be moved medially

The rigid and markedly thickened tractus ilio tibialis which was exposed through the same incision was incised at the beginning in order to correct the valgus of the knee In both cases the valgus and the medial gap in the joint were spontaneously corrected when the ilio tibial tract was cut (see Fig 4 before operation, and Fig 11 after operation)

The defect created laterally by the transposition of the extensor apparatus was to large to be completely covered by the flap which was transposed from the medial side and additional cover was obtained from the distal pedicaled flap formed by the cut ilio tibial tract For this reason the ilio tibial tract should be cut at a sufficiently high level (Fig 6 B)

After the second stage operation the hip was included in the plaster cast and was immobilized in slight flexion to release tension of the rectus muscle The cast was removed after four weeks and replaced with a plaster cast allowing the patient to be up and about After an

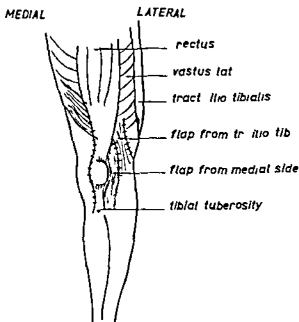


Fig 6 b

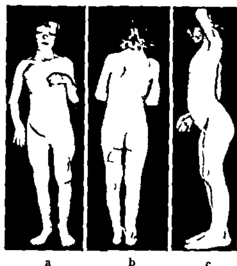
Diagram showing the situation after operation The rectus muscle and patella have been brought into a normal position The tibial tuberosit has been transposed more mediall and fixed with two nails Defect on lateral side is covered with flap from the medial side (pulled under the rectus tendon) and with part of tractus ilio-tibialis

other three weeks the cast was removed and moving exercises were started

Upon control examination four months p o of case 2 the patella appeared to be located in front of the lateral condyle and six months later a correcting operation was done when the tibial tuberosity was moved another centimeter in a medial direction A new medial strip two centimeters wide was prepared and transposed to the lateral side to cover the new defect X ray control now showed the patella in the mid line

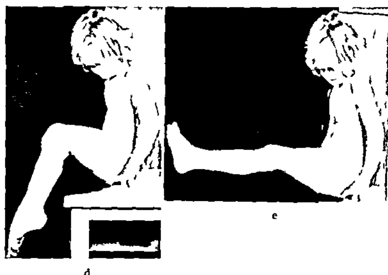
RESULTS

Case I Examination three years after the operation the patient walks and runs normally without a limp She is able to bend her knee 90 + 20 (Fig 7) She can also extend her knee fully from a hanging position of the leg against some resistance In the prone position flexion to more than 90 is performed with good force The knee shows a straight



a b c

Fig 7
Marit L Three years after operation patella in normal position No valgus of the knee Both lower limbs equally long Flexion of the knee 90 full active extension with unsuspended leg



d e

axis with no valgus Patella is felt in front in the mid line (Figs 8 A B C)

Case 2 Examination 1½ years after the operation reveals a slight limp which was attributed to her dysplastic hips (Trendelenburgs symptom slightly positive) However the pronounced limp and equinus which she had before the operation were no longer present She could bend her knee 90 + 5 and had full active extension on a hanging leg The valgus was eliminated on the operated side (Fig 9) A tangen





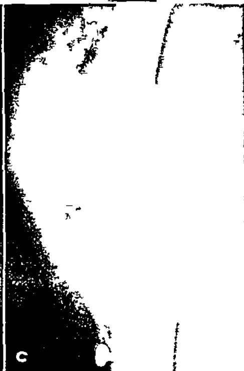


Fig. 9

a. Marit L. Roentgenogram of left knee after operation, tangential view; patella in *normal position*

b. Marit L. Roentgenogram of left knee three years after operation. No medial gap of the joint, no valgus. Patella in the mid line

c. Marit L. Roentgenogram of left knee three years after operation, lateral view; patella in normal position. The fragmentation and calcification seen at the lower pole may be seen normally. Note dorsal position of fibula is still present



a b c

Fig 9
Berit D The operated left knee as seen 1½ years after operation Patella in normal position No valgus Flexion to 90 with good force Full active extension



d e



Fig 10
Berit D Roentgenogram of left knee 1 ½ years after operation tangential view patella in normal position



Fig 11
Berit D Roentgenogram of left knee 1½ years after operation no medial widening of the joint no valgus patella in the midline

trial roentgenogram showed the patella in the midline (Fig 10) and the medial gap in the joint was no longer present (Fig 11)

SUMMARY

Congenital complete irreducible dislocation of patella is a rare condition but may be less rare than formerly believed It is suggested by the author that some cases of permanent complete dislocation of the patella in adults may be of congenital origin The author has observed a patient who had gone through a long span of life with a total irreducible dislocation of patella almost without symptoms from her knee Admittedly in this case symptoms from the knee may have been overshadowed by a concommitant bilateral rather painful disorder of the hips but it was felt that the patellar dislocation was of congenital origin

Although the condition thus may give no considerable symptoms

throughout life it may in some cases lead to pronounced and progressive disability already in childhood as shown by the two cases reported in the present paper and therefore the recognition of the disorder is important

The disability is due partly to the inefficiency partly to the abnormal function of the extensor apparatus of the knee The resulting typical clinical picture is flexion contracture and valgus of the knee and outward rotation of the leg

These cases necessitate a more radical operation than even severe cases of irreducible complete patellar dislocation of the common type and the operation has to be performed in two stages

Stage I Correction of the flexion contracture

Stage II Radical transposition of the extensor apparatus with the patella Correction of the valgus position is obtained by incision of the ilio tibial tract The operative procedure is described

The author has operated two girls five and eight years old The results in both cases were peermanent and excellent as judged by clinical and roentgenological examination after three and 1½ years respectively

RESUME

Une dislocation congénitale totale et irreductible de la rotule est une maladie rare peu traitee dans la litterature Elle est cependant plus frequente qu on l avait suppose autrefois etant donné que certains cas de luxation totale permanente chez les adultes peuvent etre congenitaux L auteur a ainsi observe le cas d une malade qui avait eu pendant la plus grande partie de sa vie une luxation totale irréductible bilaterale de la rotule sans que la maladie l ait notoirement genée Peut-etre était ce parce qu elle souffrait simultanément d une maladie congénitale bilaterale de la hanche tres douloureuse que les ennuis provenant des genoux étaient restes dans l ombre

Bien qu il puisse donc arriver que la luxation patellaire congénitale totale donne peu de symptomes l auteur montre qu elle peut déjà dans la plus tendre enfance provoquer une invalidité croissante et qu il est important de poser a un stade precoce le diagnostic et de pratiquer l operation

L auteur decrit les symptomes caractéristiques qui n ont pas ete decrits anterieurement dans la litterature Par ailleurs il decrit la methode operatoire L intervention doit avoir lieu dans ces cas en deux temps et elle est beaucoup plus radicale que celle habituellement appli

quee meme dans le cas graves de luxation patellaire totale et irreductible

L'auteur a operé deux fillettes agées respectivement de 5 et 8 ans Après une periode d observation de 3 ans et de 1 an et demi les resultats ont pu etre consideres comme tres satisfaisants

ZUSAMMENFASSUNG

Kongenitale nichteinrenkbare Totalluxation der Patella ist ein seltenes in der Litteratur wenig besprochenes Leiden Es ist doch wahrscheinlich ein häufigeres Leiden als angenommen da gewisse Falle von permanenter Totalluxation bei Erwachsenen einen kongenitalen Ursprung haben konnen Der Verfasser hat zum Beispiel eine Patienten gesehen die einen grossen Teil ihres Lebens mit einer doppelseitigen uneinrenkbaren Totalluxation der Patella behaftet war ohne dass das Leiden erwähnenswerte Beschwerden hervorgerufen hatte moglicher wiese doch weil sie gleichzeitig ein doppelseitiges schmerzvolles angeborenes Huftleiden hatte das eventuelle Beschwerden von seiten der Knice in den Hintergrund drangte

Obwohl es also vorkommen kann dass die Totalluxation geringe Symptome gibt weist der Verfasser nach dass sie bereits im frühzeitigen Kindesalter zu einer zunehmenden Invaliditet fuhren kann und dass die Diagnose und Operation im Frustadium wichtig ist

Der Verfasser beschreibt die charakteristischen Symptome die bisher nicht in der Litteratur beschrieben worden sind Weiterhin beschreibt er die Operation die in diesen Fallen zweizeitig ausgeführt werden muss und die bedeutend radikaler ist als die welche gewohnlich selbst bei schweren Fallen von nichteinrenkbarer Totalluxation der Patella angewendet wird

Der Verfasser hat zwei Mädchen im alter von 5 beziehungsweise 8 Jahren operiert Das Ergebnis wird nach 3 und 1½ Beobachtungszeit vorgewiesen und kann als sehr gut bezeichnet werden

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From the Orthopædic Clinic Malmö Sweden

A COMPRESSION INSTRUMENT FOR USE IN HIP JOINT ARTHRODESIS WITH NAILING

By

LARS UNANDER SCHARIN

In the method initiated by *Watson Jones* and *Lindström* for hip joint arthrodesis with partial intra plus extra articular arthrodesis with simultaneous nailing it is important that the nail should secure a good position As a result the patient can be treated post operatively without fixation in plaster and the leg can bear weight 6 weeks afterwards The nail should be steeply inserted and after it has passed centrally through the collum and caput it should proceed into the posterior region of the pelvis Those who have performed this type of arthrodesis have certainly noticed the complications which may arise These complications are as follows

1) The nail may be incorrectly positioned too far forward or behind or more frequently it is directed too far medially This may occur even if guides are used for the nail must pass for a good way through bone and then the ability of the guide to direct the nail is not sufficient This is especially so if the bone is sclerotic

2) As the nail goes a different path from the guide a crack may occur in the guide and this forms an obstacle both to bringing the guide out and to inserting the nail further if it is considered that the guide should be left in position

3) A diastasis may form between caput and acetabulum especially if the acetabulum is sclerotic The more one hits the head of the nail the larger the diastasis becomes

All these circumstances are for obvious reasons an obstacle to a *favourable surgical intervention*

The surgeon must attempt to take out the nail The extractors usually found on the market are not suitable for the nail is very steeply positioned and the extractors with which the nail is knocked out are almost always too slender Both these extractors can moreover

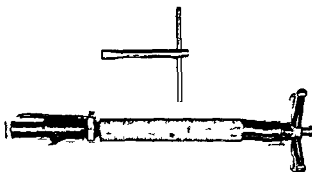


Fig 1

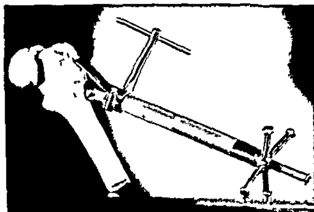


Fig 2

bring about injuries to the skeleton especially to the femur at the lower end of the nail In addition when attempting to knock out the nail it is easy to cause positional changes which can lengthen and complicate the operation

In order to overcome this difficulty I constructed in collaboration with a technician at the Orthopedic Clinic in Harnosand a nail extractor which also functions as a compression instrument (see Fig 1) It is so constructed that the instrument s application against the lateral corticalis surface can be angled exactly according to the position of the nail The application surface has small notches which do not harm the bone (Fig 2) It functions as a compression instrument in those cases in which diastasis has arisen through counter coup effect In turn the diastasis is screwed together and hard blows are struck with

a heavy metal hammer The instrument is also longer than normal extractors and this is an advantage with respect to the nature of the incision It is not necessary to concern oneself with contact between the soft parts and the screw mechanism

The situation may occur in which the guide cracks and cannot be extracted while the nail is wedged firm Then it is best to clip off the guide and knock it against the nail with a narrow punch so that the extraction instrument can be applied When the nail has been later removed the guide can also be easily extracted from the bone

This instrument is used at the Orthopedic Clinics of Härnosand and Malmo for nailing arthrodesis We consider that the operation is much simplified by this

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The meeting of the Scandinavian Orthopaedic Association was held in Helsingfors under the Presidency of A Langenskiold

TRAUMATOLOGY OF THE FOOT AND THE ANKLE JOINT

LIGAMENT INJURIES OF THE ANKLE JOINT

by *Ragnar Magnusson* (Linkoping Sweden)

The ligaments of the ankle joint can be conveniently divided into two groups which are distinctively different functionally and thus also traumatologically The one group comprises those ligaments which attach the tibia and fibula to the talus and calcaneus i e the deltoid anterior and posterior talofibular ligaments and the calcaneofibular ligament To the second group can be assigned those ligaments included in the distal tibiofibular syndesmosis namely the anterior and posterior tibiofibular ligaments and the interosseous ligament

Injuries to the ligaments of the first group arise as a rule as alternative injuries to malleolar fractures while ligament injuries in the second group almost always occur together with malleolar fractures and in certain cases are compulsorily attendant upon these

With a supination trauma the first injury which may arise is a transverse fracture of the lateral malleolus But if the trauma is of only slight or moderate degree an avulsion of the fibular collateral ligament is found instead with or without a small shell shaped fragment from the tip of the fibula According to *Lauge Hansen* it is the calcaneofibular and the posterior talofibular ligaments which are affected Correspondingly it is possible with a pronation trauma to find the first injury to be an avulsion of the deltoid ligament instead of a fracture of the medial malleolus that the injury is very often localised to the insertion on the medial malleolus Sometimes here too a small fragment may be avulsed from the tip of the malleolus On clinical examination swelling and palpatory tenderness are usually found above the tips of the malleoli or above the ligament itself Ruptures of the fibular collateral ligaments and of the deltoid ligament can be diagnosed radiologically by placing the foot in varus and valgus position thus one can confirm an increased distance between the talus and the tip of the fibula between the talus and the medial

malleolus and confirm also that the articular surfaces of the tibia and talus d not run parellel with each other

The most common injury in this group is undoubtedly rupture *of the anterior* talofibular ligament which occurs according to *Lauge Hansen* through inward rota tion of the supinated foot We all know the syndrome well with swelling and palpatory tenderness above the lateral portion of the dorsal foot and above the sinus tarsi According to *Lauge Hansen* a rupture of the calcaneocuboid ligament is also possible in such instances sometimes with an avulsion fracture from the lateral portion of the calcaneus or from the cuboid Injury to the anterior talofibular liga ment and to the calcaneocuboid ligament cannot be diagnosed radiologically accord ing to *Lauge Hansen* However an avulsion of the lateral portion of the calcaneus or of the cuboid may occur according to the same author and this can sometimes be seen on the X ray

In ankle joint distortion injuries to tendon sheaths and joint capsules may al arise Tendon sheath injuries are hardly likely to contain any serious complication *As far as injuries to the joint capsules are concerned it is difficult to make any* definite statement Under certain circumstances they may possibly contribute to the manifestation of certain tendon trouble but our knowledge of these matters is still too small for us to express an opinion on this with any great precision

The group of ligamental injuries briefly discussed here is a very common group Since the injuries are often considered to be trifling they receive treatment corre sponding to this approach which often consists of the application of some form of elastic bandage etc It is undeniable that a great number of these patients become free from symptoms after such treatment or even without any treatment at all This may be explained by the circumstance that a rupture may not always occur but that the injury may confine itself to a strain or distension of the ligament If a skeletal injury is excluded the next step is to try and determine whether a strained ligament or ruptured ligament is involved In differential diagnosis between these two types of injury to the collateral ligaments the gap demonstrated by *Lauge Hansen* between the talus and the malleoli can be utilised as this in all probability only occurs in total ruptures but not in strained ligaments Here perhaps arthrography may help to shed light on a number of obscure points

In a large series of ankle joint distortions *Brostrom* found that the progno is for treatment with a simple supporting bandage was good even if total rupture of the ligament was present Other authors *e g Francillon Watson Jones* etc recommend immobilisation for 6 weeks for injuries to the collateral ligaments It i in each case important to remember that a ligament requires a longer period to heal than a fracture

With persistent insufficiency in a ligament instability arises and in consequence recurrent distortions may occur Even a quite insignificant awkward tep can give rise to new trouble and it is not rare to meet patients who incur a di t rti n merely by walking on a level smooth city street In the long run rupture of collateral liga ments which do not heal cause deforming changes in the talocrural joints In cases with frequent distortions suturing of plastics should be performed F r the latter purpose a number of methods have been evolved

I shall now pass on to describe injuries to the second group of ligaments the syndesmosis injuries They may arise either as *isolated* injuries with ut simultane ous fracture or as *injuries compulsorily attendant upon certain* type of malle lar

fracture An injury to the syndesmosis may either affect one of the ligaments a partial syndesmosis a total syndesmosis injury In both cases pre-conditions exist for the appearance of a widening of the malleolar fork a diastases Whether a partial or total widening of the malleolar fork occurs a lateral subluxation of the talus appears on weight bearing by the foot

The most common malleolar fracture is the oblique fracture of the fibula which occurs through outward rotation of the talus when the lower leg is fixed Before the fibula fracture establishes itself there is *always* a rupture of the forward syndesmosis ligament the anterior tibio fibular ligament It is anterior syndesmosis injury which determines the appearance of the oblique fracture of the fibula With this type of malleolar fracture on the other hand the posterior syndesmosis ligament always remains intact

The injury to the forward syndesmosis ligament arises most often as an avulsion fracture from the tibial attachment the anterior tubercle of the tibia but ma also occur as a pure soft tissue injury or as an avulsion fracture from the attachment on the fibula The small shell shaped fragments which are avulsed from the tibia are too tiny to be seen on the X ray picture when the injury occurs If the avulsion fracture does not heal sclerosis occurs in the small avulsed fragment and this makes the fragment visible after a time in the frontal X ray picture On X ray examination of the foot in 4 outward rotation the anterior tubercle is projected free and then a possible pseudarthr sis can be obtained on the X ray picture When the ligament is avulsed from the tibia without a bony fragment one can after a time see changes in the contour of the anterior tubercle of the tibia

With a pronation trauma the first injury to occur is a transverse fracture of the medial malleolus or a rupture of the deltoid ligament The second injury is a syndesmosis injury comprising both the anterior and the superior syndesmosis ligaments a total s ndesmosis injury With a pronation trauma as is well kn wn the fil ula fracture ma occur in any part of the fibula at all even sub capitularly With the high types of fracture there is according to *Lauge Hansen* an injury n both anterior and posteri r s ndesmosis ligaments and also a rupture f the inter sseous ligament With the more distally sited pronation fractures the same author finds injury only to the syndesmo is ligaments while the interosseous ligament remain intact

In a further type of malleolar fracture rupture of the anterior syndesmosis l ga m nt occur i e with the quite uncommon bimalleolar supination fractures with me lial subluxation of the talu In these fracture an avulsion occurs of the anteri r and prcbal ly also of the p terior syndesmosis ligament but on the other hand n s n lesmo is rupture which is imp rtant to remember In this type of fracture the distal fibula fragment always follows the talus with medial disl cation

It is easy to diagno e s ndesmosis injuries with simultaneous occurring fracture As on as the etiol gical diagnosis of the fracture is clear then one al o kn ws what kind f ndesmo is injury is pr ent It is prol ably unusual to see a syndes m i injury in uch cases offers great diffi ulty A symptom which arise however swelling and palpat ry tenderness above the anteri r portion f the yndesm sis Thi mpt m is very characteristic but clearl quite unfamiliar

The attempt ha been made to deal with the difficulties in the diagnosis of the s n le m sis injuries by means of a few r di logical metho ls On the one hand a number of measuring method exist which are all variations n the ame theme

that is to measure in different ways the distance between the tibia and the fibula and on the other hand diagnosis of syndesmosis injuries by means of arthrography has been attempted It would take too much space to describe these methods in more detail in this connection One may say briefly of the measurement methods that the sources of errors are too many for the method to give reliable results and as far as the arthrography is concerned that it is a little too involved and that it is hardly suitable for an out patient practice where it otherwise would have its greatest value It is then really simpler after anaesthesia of the joint to carry out lateral disloca tion movements under X ray control in order to discover if the talus can be success fully dislocated I will instead once again emphasise the extreme importance of mastering the etiological diagnostics of malleolar fractures Then one need have no worry about finding out whether a syndesmosis rupture exists or not and if it is present then one also is aware of what it comprises

The treatment of a fresh *syndesmosis injury without fracture* consists in immo bilisation of the foot in the inward rotated position for at least 6 weeks With *simultaneous fracture* the treatment of syndesmosis rupture and fracture coincides For immobilisation of the foot whether after open or closed reduction of the fracture the foot must be placed in the position which makes possible healing of the syndesmosis injury For outward rotated fractures the foot must be therefore fixed in the inward rotated position and for pronation fractures in the supination position The period of immobilisation must naturally be adapted to the severity of the fracture

Swelling and palpatory tenderness above the anterior aspect of the syndesmosis that is the symptom which I have mentioned as typical of a fresh syndesmosis injury may remain over long periods and is then a sign that the syndesmosis injury is not healed The patient s subjective symptoms in this respect are often a feeling of uncertainty on walking stiffness and pain in the ankle joint Swelling around the ankle joint often occurs especially in association with exertion and this is a symptom of an initial deforming arthrosis As far as the incidence of deforming changes in the ankle joint is concerned it should be stated that amongst 118 cases of unimalleolar outward rotation fractures there were 35 cases with arthrosis deformans in the injured ankle joint equal to 29 per cent The observation period was on average 5½ years *Watson-Jones* spreads a dangerously false opinion there fore when he states in his book on fractures that for the treatment of this type of malleolar fracture it matters little what is done"

The idea has begun to gain acceptance that the normal width of the malleolar fork should be restored when there is a diastasis in the fork. Various surgical procedures have been utilised for this purpose The most common is probably to fix the fibula to the tibia with a wing screw This procedure has the disadvantage that it is diffi cult to judge how much the screw should be tightened If it is tightened too severely then less width will be found in the syndesmosis than is normal with the accom panying loss of the elasticity normally present is the syndesmosis This can produce difficulties in the gait when walking A loop of steel wire may also be utilised to fix the fibula to the tibia a procedure which does not perhaps provoke the same silent restistance in the talus movements in the fork as may be the case when the screw is used Before any of these procedures are utilised however one should first of all see whether any ligament rupture present can be sutured or whether the pseudarthrosis which may possibly have arisen within the anterior tubercle of the

tibia can be treated *Cedell & Wiberg* have noted well the danger of a permanent diastasis and with fresh outward rotation fractures they have performed cerclage on the fibula and treated the syndesmosis rupture by fixation with a metal clamp or by suturing the syndesmosis ligament and with subsequent immobilisation for 6–8 weeks The syndesmosis injuries surgically treated up to this point are either too small in number or as in *Cedell & Wiberg's* series too little time has passed for any evaluation of the different methods to be made

I have tried to make a brief survey of the diagnostic and therapeutic problems which meet us in injuries to the ligaments of the ankle joint It is clar that there is much to add but I hope that the coming discussion will give more comprehensive information about the interesting complex of problems called *the traumatology of the ankle joint*

TREATMENT OF MALLEOLAR FRACTURES

by *Kauko A Solonen* and *Leo Lauttamus* (Helsinki)

Fractures of the ankle have often been dealt with in the literature and a number of valuable studies have been made by Scandinavians (*Hasfeldt* 1938 1939 *Lauge Hansen* 1942 1948 1949 1953 1956 *Magnusson* 1944 1945 *Palmer* 1946 1950 1961 *Kristensen* 1949 1953 1956 *Bistrom* 1952 *Vasli* 1957 *Grath* 1960 *Klossner* 1962) When undertaking to describe in the following experience obtained in the treatment of fractures of the ankle we make no claim to a new method nor do we promise a parade of brilliant results We have worked on traditional lines and quite possibly some other writers may be able to present better end results. The purpose of the study has been to scrutinize our own work and to discover where mistakes have been made

The fractures are here classified according to the Lauge Hansen–Palmer system the one most commonly used in the Scandinavian countries in which the groups are clearly distinct and which is logical and serviceable (Fig 1)

Malleolar fractures besides being dependent on the nature of the trauma and other injury mechanism involved are also to a great extent conditioned by the ligamentous anatomy of the ankle It may be said that were it not for problems of the ankle ligaments the treatment of malleolar fractures would present no great difficulty Quite often injury done to the ligaments is of much more significance than the fracture after which the damage is named On the whole injuries to the malleoli and the ligaments occur simultaneously with and are equally significant components of damage caused to the ankle

Material

The study is based on two groups of cases an older series which was examined during the course of a number of years and a more recent series of which only the primary results have been analysed The older series derives from a time when the Clinic was housed in the same building with two other clinics and most of the fractures were treated primarily by general surgeons The newer series was treated at the Clinic for Orthopaedics and Traumatology

In all 8[illegible]1 patients with fractures of the malleoli treated in the years 1950–1963 were examined The figure omits the out patients treated within the same period In

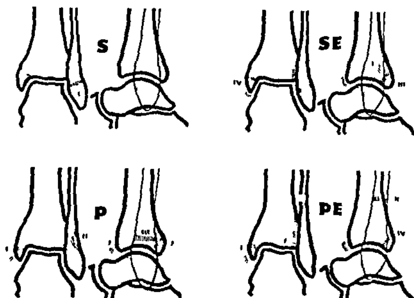


Fig 1

Lauge Hansen Palmer classification of injuries to the ankle
S = Supination
SE = Supination external rotation
P = Pronation
PE = Pronation external rotation

some of the cases included in the series not of a severity to necessitate hospitaliza tion the patients were admitted to the hospital because of other contemporaneous injury

The series consists of an almost equal number of men and women but the two sexes show considerable divergence in age distribution Of the women 4/5 were 40 years old or more of the men oly one half Of the women a third were 60 years or more of the men only 1/10 were of that age

The first series observed during a longer period of time comprises 238 patients treated in 1950–1960 Of these 116 patients (about 49 per cent) presented themselves at follow up examinations The distribution of fractures of this group of cases into types and degrees is shown in Table 1 The cases that were followed up will be seen in Table 2 The distribution of the follow up series among different types of frac tures as appears from the Table corresponds with the ratio in the whole series The exceptionally large share of the pronation—external rotation fractures (PE 27 per cent) attracts attention In other series published the percentage has ranged between 7 and 23 The time that elapsed between the injury and the follow up was 2 12 years Judging from the primary results in most of those who did not present themselves for follow ups the end results were good i e our follow up results give an un favourable picture of the results of treatment The distribution of the newer series among different types is shown in Table 3

TABLE 1

Distribution of fractures among the various groups and stages (1950–1960)

Fracture group	Stage II	III	IV	Total	
S	22	–		22	9
SF	2	9	108	119	50
P	6	17		23	10
PL	–	9	47	56	23
Irregular			18	18	8
Total				238	100

S = Supination
SF = Supination external rotation
P = Pronation
PF = Pronation external rotation

TABLE 2

Follow up series (1950 1960)

Fracture group	Number of patients	
S	9	8
SF	58	50
P	11	9
PF	31	27
Irregular	7	6
Total	116	100

TABLE 3

Distribution of fractures among the various groups and stages (1961–1963)

Fracture group	Stage II	III	IV	Total	
S	5	44		49	8.4
SF	16	8	327	351	60.2
P	21	23		44	7.5
PF	1	15	91	107	18.4
Irregular			32	32	5.5
Total				583	100.0

Treatment

Of the older series (238 cases) 191 (80 per cent) were treated conservatively and 47 (20 per cent) by operation In recent years operative treatment has been resorted to nearly twice as often as earlier Of the 583 patients in the new series 214 were operated upon (37 per cent) and in 369 cases (63 per cent) the treatment was conservative

Conservative treatment

No clear cut indications were followed in the choice of operative procedure the aim was to select the method considered the most appropriate in each individual case The largest group operated upon was that in which the attempt to treat the damage conservatively had led to an unsatisfactory outcome The commonest reasons for this were interposition in the fracture of the medial malleolus syndesmotic rupture and a large fragment of the posterior tibial margin In many cases repair of the fracture was accompanied by suturation of a ligamentous rupture The ligament in question was usually l deltoides In three cases a primary talocrural arthrodesis was carried out with a good result All the ankles operated upon were immobilized in plaster of Paris in the same manner as those treated conservatively A walking cast was applied in both series in about two thirds of the cases 4–6 weeks after the primary treatment

Results

The primary result (result after the end of the primary treatment) was evaluated from roentgenograms and case records The end result was evaluated in the follow up (We are personally responsible for all the evaluations) The results have been classified as good fair and poor

In the primary estimate a roentgenographically good result was taken to mean exact reduction of the medial and lateral malleoli and talus In addition the result was considered good if the fractural line in the medial malleolus was open 2 mm at the most in the ventral direction the fragment of the lateral malleolus had not shifted more than 1 mm proximally or dorsally The fragment of the posterior margin measuring less than ¼ of the width of the distal articular surface of the tibia measured on the lateral aspect was not to be dislocated upwards more than ? mm at the utmost For a fair result an accurate reduction of the talus was required a widening of 1 mm at the most in the ankle mortise and a shift of not more than 2 mm of the fragment of the lateral malleolus in the proximal or dorsal direction or a distal or anterior dislocation of the fragment of the medial malleolus not exceeding ? mm or a not more than 2 mm displacement upwards of the large fragment of the posterior margin Results inferior to these were considered poor primary results roentgenographically A roentgenographic late result was estimated as good if a good reduction result of the kind described was recorded with only slight arthrosis The late result was fair roentgenographically if only slight arthrosis was present in connection with the above satisfactory reduction or severe arthrosis concurrent with a good reduction result Results inferior to these were estimated as poor

The cases were estimated as clinically good if the injured ankle was equivalent to a sound one Clinically fair were the cases in which no deformity of the ankle was revealed and in which the dorsal and plantar flexion of the ankle was at least one

TABLE 4
Results of treatment (1950 1960)

Treatment group	Primary result			Later result								
				Subjective			Clinical			Radiographic		
	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor	Good	Fair	Poor
S	2	3	4	4	4	1	5	2	[illegible]	1	6	2
SI	27	13	18	36	18	4	39	12	7	24	15	19
I	7	3	1	9	1	1	9	1	1	6	4	1
II	15	8	8	19	8	4	22	4	5	13	9	9

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Results

The primary result (result after the end of the primary treatment) was evaluated from roentgenograms and case records The end result was evaluated in the follow up (We are personally responsible for all the evaluations) The results have been classified as good fair and poor

In the primary estimate a roentgenographically good result was taken to mean exact reduction of the medial and lateral malleoli and talus In addition the result was considered good if the fractural line in the medial malleolus was open 2 mm at the most in the ventral direction the fragment of the lateral malleolus had not shifted more than 1 mm proximally or dorsally The fragment of the posterior margin measuring less than 1/4 of the width of the distal articular surface of the tibia measured on the lateral aspect was not to be dislocated upwards more than 2 mm at the utmost For a fair result an accurate reduction of the talus was required a widening of 1 mm at the most in the ankle mortise and a shift of not more than 2 mm of the fragment of the lateral malleolus in the proximal or dorsal direction or a distal or anterior dislocation of the fragment of the medial malleolus not exceeding 2 mm or a not more than 2 mm displacement upwards of the large fragment of the posterior margin Results inferior to these were considered poor primary results roentgenographically A roentgenographic late result was estimated as good if a good reduction result of the kind described was recorded with only slight arthrosis The late result was fair roentgenographically if only slight arthrosis was present in connection with the above satisfactory reduction or severe arthrosis concurrent with a good reduction result Results inferior to these were estimated as poor

The cases were estimated as clinically good if the injured ankle was equivalent to a sound one Clinically fair were the cases in which no deformity of the ankle was revealed and in which the dorsal and plantar flexion of the ankle was at least one

TABI I C

I rimary results in the later eries (1961–1963)

Tr 1 1	SI						I			II			I r g 1		
	(1	F ir	I or	(o l	I air	I r	(o l	I ir	I or	Co l	I ai	I r	(1	I air	I or
(nservative	28		2	153	56	30	21	5	5	31	10	9	13	5	1
Oj erative	15	2	2	70	32	10	9	3	1	38	12	7	9	3	1
Tc tal	43	2	4	223	88	40	30	8	6	69	22	16	22	8	2

the final results is found in Table 5 and shows 33 per cent of definitely good results 47 per cent of fair and 20 per cent of poor results

When the results are examined by types of fracture the poor results of fractures in group S are found to be due to incidental complications and unsatisfactory early treatment given elsewhere

The *good results obtained for SE fractures have persisted Part of those that were* fair primarily have been good at follow up Even the roentgenographic result has sometimes improved new bone filling up bone defects left after primary treatment such as are due to rise of the posterior marginal fragment of the tibia or a shift of the malleolar fragment In group SF only slight widening of the malleolar mortise caused by a partial syndesmotic rupture was present but in most cases the unsatisfactory results seemed to be traceable to the residual dislocation of the fragment of the lateral malleolus *The results of the fractures in group P had persisted*

The PE fractures often showed a poor result which was due to an insufficient syndesmosis and lateral subluxation of the talus In three cases a late arthrodesis proved necessary The primarily good and fair results had persisted

The results are better in the new series (Tables 6–7) A good result was obtained in 66 per cent a fair one in 22 and a poor one in 12 per cent of the cases In this material good fair and poor results were obtained in the same ratio in the groups treated conservatively as in those in which the patients were subjected to operation

TABLE 7

Summary of the primary results (1961–1963) (%)

Fracture group	Good	Fair	Poor
S	88	4	8
SE	64	25	11
P	68	18	14
PE	64	21	15
Irregular	69	25	6

The fractures not represented in the Lauge Hansen system (irregular fractures) 6 per cent in the older material 5½ per cent in the newer were not examined in detail The whole series it should be mentioned contains about 5 per cent of unanalysed open fractures

Discussion

In about 20 per cent of the cases two or more reductions had to be performed if those undertaken on the same occasion are counted as one procedure Judging from the frequency of the procedures the fractures of group PF were the most difficult to treat The great number and differing qualifications of the surgeons participating in the treatment must of course have affected the results Secondary arthrosis not always *ascribable with certainty to the injury in question* was revealed by roentgenography in 61 per cent of the patients followed up This i an exceptionally high percentage The relatively higher incidence of arthrosis in the patients operated upon than in those treated conservatively also appears exceptional Whether this is to be

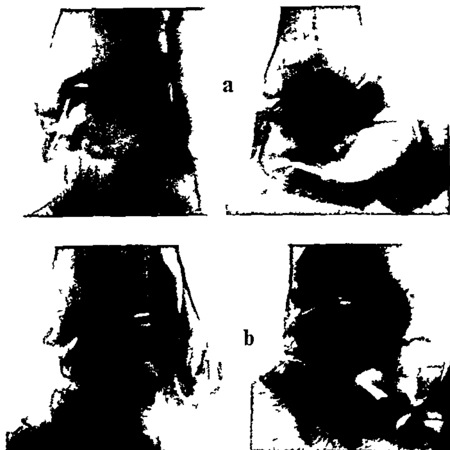


Fig 3
Arthrographic findings
(a) A normal ankle (b) Rupture of the lateral collateral ligaments.
(c) A syndesmotic rupture

attributed to the fact that only the most severely injured ankles were subjected to surgery as well as ankles on which conservative treatment had been attempted in the first instance or to the procedure itself remains an open question

A widened *tibiofibular syndesmosis was revealed in more than 27 per cent of the* cases in the older series and in 14 per cent in the newer Most of the cases occurred in consequence of fractures of group SE. Of the cases of the SE group 33 per cent showed some degree of syndesmotic widening The condition was of almost equal relative frequency but in a severer stage in group PE, and rare in group P As can be concluded from this distribution among the different groups, the majority are partial ruptures mainly ruptures of the anterior tibiofibular ligament (SE) A widening of 1 2 mm on the whole does not seem to cause any subjective discomfort This is also the view expressed by *Klossner* among others Primary detection of a

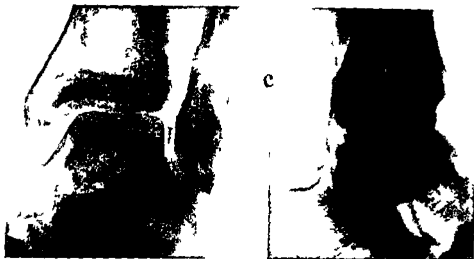


Fig 3

partial syndesmotic rupture is often considered difficult and many methods have been suggested to facilitate diagnosis (*Chaput* 1908 *D Aubigne & Smets* 1934 *Felsenreich* 1937 *Johansson* 1938 *Husfeldt Magnusson* 1944) Even arthrography has been utilised (*Wolff* 1940 *Hansson* 1941) Yet familiarity with the Lauge Hansen classification seems to resolve the difficulty in a satisfactory way and makes special measures of examination superfluous *Quigley* (1959) recorded a similar view Arthrography is not out of place but its best use is in revealing ruptures of the lateral collateral ligaments (Fig 3)

It has been claimed that it is possible to omit removal of the appliance of fixation a screw or a bolt without causing restriction of mobility or other noteworthy inconvenience (*Costigan* 1953 *Mullins et al* 1958 *Grath Smith* 1963) but a number of dissident views have been recorded (*Alldredge* 1940 *Burns* 1942 *Lee & Horan* 1943 *Bonnin* 1950 *Close* 1956) Our follow up series contained patients with a broken fixation screw and a few others with ossification of the syndesmosis in others on the other hand a reaction of the bone tissue around the screw was revealed along with resorption of the bone and surrounding sclerosis The findings were similar whether the screws applied were of steel or vitallium None of these patients were wholly free from subjective symptoms In the newer series the same findings were revealed in 22 cases *i e* in most of the cases in which the screw was retained The reaction in the bone tissue surrounding the screw was revealed by roentgenography at the earliest after the lapse of three weeks from the operation No reaction was seen in any instance around the malleolar screws with the exception of one case with a mobile pseudoarthrosis in the malleolus (*Fig* 4) It would appear that in our series repair of a syndesmotic lesion or fixation of the syndesmosis was carried out too infrequently On the other hand we are assured that the syndesmotic screw should preferably be extracted before weight bearing The movement of the fibula in the direction of its longitudinal axis around it and in the mediolateral direction is surely not without significance for the functioning of the ankle although in some cases if eliminated subjectively insignificant symptoms are produced

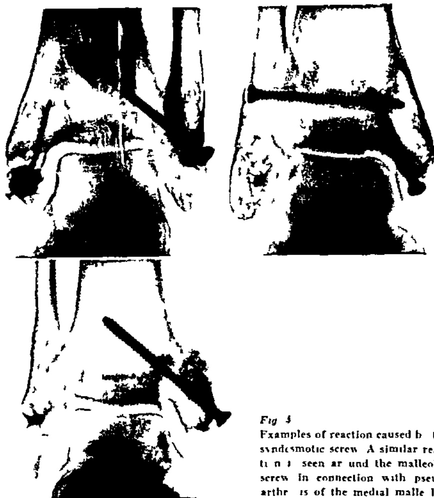


Fig 4
Examples of reaction caused b the syndesmotic screw A similar reac ti n i seen ar und the malleolar screw in connection with pseud arthr is of the medial malle lus

Ligamentous lesi n were pre ent ce rding to Lauge Hansen s cla sification in the m j rit f ur ca es i in all fractures of gr up SE, P and PE Yet only one in tanc of clinical in ufficienc of th ligaments was revealed in the follow ups No pecific roentgenog aphy wa carried out to demonstrate ligamentous insufficiency The great numl er f in tanc f syndesm tic widening an I disl cations of the lateral malleclus sh ul I however be ascril ed t omissi n in the treatment of the ligament u damage In ur opini n ligamentou rupture shoul I be sutured unless the treatment f the fractures quite I viously mak s it possil le f r the lig ments to be re t re I anat mically Exper ments ugge t th t quicker an I I tter regenerati n f the lig ments i achi ved I y utur li n than thr ugh cicatrizati n (*Clayton t al* 19 9) S me in t nce f o ifi ati n of the lig m nt were revealed after the liga ment u uptur (Fig 5) Om i n f an exa t reducti n and retenti n f th lateral





Fig 5 Fig 6

Fig 5 Pseudarthrosis of the medial malleolus unaccompanied by subjective discom fort

Fig 6 Ossification of the deltoid ligament after a malleolar fracture





Fig 7

(a) Initial roentgenogram in a man nineteen years old after the injury
(b) Regional bone atrophy nine weeks later

malleolus in cases of ligamentous or syndesmotic rupture was one of the commonest causes of an unsatisfactory result After fixation of the medial malleolus exact re position of the fracture of the lateral malleolus could be effected in most cases but if fixation of the lateral malleolus was omitted dislocation especially rotation fre quently occurred It seems that in fractures of group SE for instance the best result is achieved by operative repair of both the ligamentous damage and the fracture of the lateral malleolus The advisability of this kind of treatment has been emphasized

by many writers in the past (*Palmer Rudberg* 1953 *Proctor* 1954 *Vasli Bergkuist et al* 1958 *Cedell et al* 1967)

Pseudarthrosis of the medial malleolus (Fig 6) was revealed in 8 per cent of the follow up cases It was always interpreted as implying a poor roentgenographic result Yet only one tenth of these patients complained of discomfort that could be clearly traced to the medial malleolus Severe fibrosis may it seems to us counterbalance damage to bone tissue even in cases with a large fragment Different opinions have earlier been expressed about the significance of the pseudarthrosis of the medial malleolus (*Laurent* 1956 *Nyst* 1961 *Frankel et al* 1963)

Pseudarthrosis of the lateral malleolus was present in one case

Aseptic necrosis of the fragment of the medial malleolus occurred in four cases without causing any noteworthy discomfort

The large fragment of the posterior margin of the tibia remained dislocated in 8½ per cent of the cases in the old series and in 2½ per cent in the new series after treatment This fault gives rise to a poor result In most cases the dislocation can only be treated by surgery More than one or two screws or nails may be required for retention of the fragment In connection with fractures of group SE the dislocation of the fragment of the posterior margin is often reparable by means of an exact reduction and retention of the fragment of the lateral malleolus for the two fragments constitute a fractural whole

Pes planovalgus was recorded in 11 per cent at follow up bilateral deformities being left out of account

The following incidental complications impaired the result splitting of the fragment at operation insufficient fixation of the fragment leading to redislocation too restricted an operative approach lesion of the articular surface of the talus other primary traumatic complications of the fractures which in some instances ruled out operative treatment and the achievement of a good result Severe bone atrophy after the fracture and immobilization was sometimes the cause of delayed recovery (Fig 7)

No additional operative complications occurred with the exception of some cases of marginal necrosis of the wound due to a faulty clumsy technique incorrect timing of the operation or a poor plaster cast It is well known that in the treatment of malleolar fractures the surgeon s technique in making plaster casts is put to an exceptionally severe test Now and then redislocation of the fracture due to an inferior plaster was revealed The previously described periods of immobilization appear to have served the purpose A walking cast is often helpful but in some cases the result was found to have been impaired through its use In these cases the fracture had been too unstable to permit treatment by this means

Conclusions

Primary results persisted on the whole but secondary arthrosis sometimes impaired an ankle which was believed to have been completely restored

A good result presuppo es an accurate diagno is achievable onl if the whole extent and genesis of the damage is understood. It is a matter of damage to several components of a complex joint and not only of fractures of the bone

In the absence of contraindications treatment should be operative if good reduction and secure retention have not been produced by the conservative treatment External rotation fractures (SE II IV and PE II–IV) should presumably always be treated by surgery A widening of the syndesmosis should be repaired The fixation

appliance used on the syndesmosis should be removed before walking without support

At operation an accurate reduction and stability should be achieved For this result an open repair of more than one component of the injury is usually required In all cases conservative reduction must be carried out at the earliest possible moment to prevent disturbance of the circulation and its consequences Correct timing is important when surgery has been decided on

Ligamentous ruptures should be sutured unless treatment of the fractures quite obviously makes it possible for the ligaments to be restored anatomically

Accurate repair of the fracture of the lateral malleolus is as important as that of the medial malleolus

The plaster cast should ensure good immobilization during the whole course of the treatment and be well moulded A walking plaster may be applied at the final stage of the treatment when the syndesmosis is firm and no significant fracture of the weight bearing articular surface of the tibia is present

Primary arthrodesis is sometimes indicated A good result is not always achievable but should always be aimed at

Summary

Experience obtained in the treatment of 821 cases of malleolar fracture is described Both primary and late results are evaluated Conservative and operative treatment were used The results of treatment were good or fair in 80–88 per cent of the cases The result obtained by primary treatment was found to persist although in some cases it was impaired through arthrosis in the course of time

Success is achieved only through full understanding of the genesis and extent of the damage and treatment of all its components Damage to soft parts especially lesions of the syndesmosis and the ligaments must be treated Surgery seems to be indicated in more cases than has been supposed hitherto especially in the repair of damage due to external rotation and specifically in the repair of syndesmotic and ligamentous ruptures and fractures of the lateral malleolus

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DIVISION INTO TYPE AND SURGICAL TREATMENT OF SUPINATION OUTWARD ROTATION INJURIES OF THE ANKLE JOINT—Series report
by *C A Cedell* and *G Wiberg* (Lund Sweden)

In recent years ankle joint injuries have been given surgical treatment to an ever greater extent

In the Orthopaedic Clinic in Lund we began in 1958 to operate on the oblique distal fibula fracture and have since devoted special interest to the supination outward rotation injuries in their 4 different stages At the Clinic during the years 1958–1963 504 ankle joint injuries were operated on 320 of which arose owing to a supination outward rotation trauma (63 5 per cent) Injuries of the 1st 2nd 3rd and 4th degrees comprise respectively 1 2 32 5 6 3 and 60 0 per cent of the series which consists of 130 men and 190 women

A special surgical procedure was gradually evolved and we can use this with small modifications for other types of ankle joint injuries also In *SO injury 1st degree* referring to a rupture of the anterior tibiofibular ligament we operate with ligament suture and metal staple which is fixed in the tibia and fibula and follows the direction of the ligament fibres In *SO injury 2nd degree* referring to a rupture of the anterior tibiofibular ligament and oblique distal fibular fracture we operate with cerclage ligament suture and metal staple (*Cedell* & *Wiberg* 1961) *R Magnusson* (1944) and *Cedell* (1962 unpublished material) when following up conservatively treated cases of stage II injuries demonstrated an arthrosis incidence of approx 30 per cent a figure which illustrates the importance of an exact fracture reduction In *SO injury 3rd degree* in which a rupture of the posterior tibiofibular ligament or a fracture of the posterior process of the tibia occurs the posterior tibial fragment rarely requires special operative measures We fix a large tibial fragment by screw In *SO injury 4th degree* where a rupture of the deltoid ligament or fracture of the medial malleolus arises we fix the malleolus fragment with a Rissler or Palmer pin.

For external fixation we utilise a lower leg plaster which the patient wears for 4–6 weeks after which weight bearing is permitted The primary results have been very good and the number of complications few Even ugly dislocated ankle joint fractures generally have a very good post operative course

The operative treatment of ligament injuries and fractures of the ankle joint should in our opinion effectively prevent the occurrence of posttraumatic insufficiency and arthrosis conditions

ARTHROGRAPHY IN ACUTE ANKLE LESIONS

by H Glastrup (Stege Denmark)

The material comprises 60 patients admitted to the hospital in Steg Denmark with acute ankle injuries

Technique

The standard projections used for X raying ankle joints are as follows

1) anteroposterior
2) lateral
3) internal rotation gi ing a iew between the tibia and fibula

The same projections are used for arthrography which is done after injection of 4 ml of a water soluble iodized contrast medium Trijodyl 17½ per cent

Diagnosis

When the contrast medium has been injected into the joint the folds of the joint capsule ought to present themsel es rounded and uninterrupted Minor leakage into ligaments or the peroneus tend in sheaths is of no importance

Oozing through fractures or along the injection needle may constitute sources of error

Material

Out of 60 in patients 32 had arthrography Operation was performed on 21

In 17 cases arthrography revealed rupture of the capsule In 15 cases the capsular rupture was confirmed by operation Two capsular ruptures were estimated as very mall

Capsular suture was done in a total of 19 cases The most severe cases did not have arthrography Experience has shown that in such cases the contrast medium oozes into the soft tissues in such quantities that it is impossible to obtain good films

At operation the injuries to the capsule and ligaments were sometimes found to be more severe than expected according to the arthrographic findings

Case Reports

Five characteristic cases were reported All showed accurate agreement between the arthrographic and operative findings

In 3 of these cases capsular suture was performed in one capsular suture + suture f the syn lesmosis and in one case uture of a severe rupture of the s nde mosis All were bandaged for 6 weeks

Instal ility of the ankle joint has n t devel ped in any case although great demands are made on ankle stability in the two patients who had rupture of the syndesmosis

Onl one patient has complaints which are greatly decreasing after a follow up period of 6 months

Finally one case of po ttraumatic complaints was described

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treated at the Department of Orthopaedi... seventh fracture was accompanied by a ... primarily diagnosed in only half of the ... ankle is recommended in all cases of l... stantial fracture dislocation supplementary ...

THE SIGNIFICANCE OF THE VALGUS D... OF THE CALCANEUS

by *So Rosendahl* (Copenhagen)

Dislocated articular fractures of the calcan... position because of the pronated position of the ... result from over correction in the reduction ... cases of dislocated articular fractures whi h ... active exercises without weight bearing and ... result was poor

In cases with a normal position of the f...

In cases with severe valgus there was 0 ...

When the position of the foot was normal 21 ... developed osteoarthritis in the subastragalar j... 69.3 per cent developed osteoarthritis

In cases with a normal subastragalar m...

In cases with abolished subastragalar m... results

Probably the valgus deformity is the cause of ... fracture and responsible for the development ... itself is not the cause of a poor result and ... guar ntee freedom from pain

Accordingly the central therapeutic measure is ... The best results are found after *Palmer* s open red... exercises without weightbearing Treatment with a ... results leading to secondary compression and ... deformity

RESULTS OF TALOCRURAL ARTHRODESIS AND ... THE ANKLE JOINT IN POST TRAUMATIC CON...

by *R Kivilaakso* *A Langenskiöld* and *P Salénius*

The series presented here covers the cases in which ... talar arthrodesis of the ankle joint were carried out in ... the Invalid Foundation Helsinki from July 1956 to June ...

The number of patients who were treated during th... desis and pantalar arthrodesis of the ankle joint ... 55 of whom 43 were men and 12 women

Arthrodesis was performed by the Adams meth... anterior surface of the tibia according ... Fixation with a long vitallium screw driven thr...

calcaneus and through the talus upwards into the tibial diaphysis was used in pantalar arthrodesis and talocruralarthrodesis when the subtalar joint was anchylosed

The Adams operation was used in 22 cases and led to bony anchylosis in all

In two of the six cases in which anchylosis was not achieved in this series the arthrodesis was performed again In one case the renewed treatment led to bony anchylosis but not in the other The fact that 4 of the 6 patients did not wish to undergo a further operation seems to indicate that fibrous anchylosis in the talo crural joint does not always cause noticeable discomfort Good results according to the patients estimation were achieved in 27 cases satisfactory in 23 and poor in 5 Objective examination showed the results of treatment to be good in 43 cases satis factory in 5 and poor in 7

RECONSTRUCTION OF DEFECTS IN THE WEIGHT BEARING SURFACES OF THE FOOT

by *Lars E Avellan* (Gothenburg Sweden)

Primary and Secondary Weight Bearing Areas

Three weight bearing surfaces may be discerned in the foot *i e* the sole the heel and the achilles region These surfaces have a special skin structure in common the skin lacks hair follicles and sebaceous glands its epidermis is thicker the connective tissue is more compact and therefore less elastic the number of pigment cells is less than elsewhere and the papillae of the cutis are arranged in double rows which are covered by simple epidermis layers The largest of the weight bearing surfaces men tioned is the sole of the foot As a result of my investigations I have determined that it is possible to distinguish between two areas in the normal sole which I have called the primary and the secondary weight bearing areas (Fig 1) The primary surface which is exposed to direct pressure from the weight of the body comprises the skin of the heel and of the lateral edge of the foot and also the skin in front of

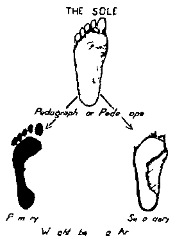


Fig 1

the heads of the metatarsal bones. The secondary surface is formed chiefly by the long arch of the foot. With the aid of the pedograph or pedescope these surfaces can be marked off from each other. The pedograph is a pressure pad by means of which a foot impression is obtained on paper, called a pedogram, when the patient steps onto the pad. The pedescope, which was constructed by *R. Bachmann* (1961), is a chair for orthopaedic examination in which the foot rests on a glass plate. With the aid of a mirror it is possible to follow the sole under various degress of weight bearing and in various lighting conditions and also record this on film. In my investigations I only had access to the pedograph which gave satisfactory information about the primary weight bearing surface.

Reconstruction of Defects

Is it necessary to analyse the foot sole before a defect in its is reconstructed? In the examination which I made of patients with defects in the primary weight bearing surface which were reconstructed according to conventional methods, i.e. by direct suturing, by split skin grafting, by full thickness skin grafting from hair bearing areas, by local or distant flaps or tubes, crossleg, I found in all 20 cases hyperkeratosis in the zone bordering on the intact skin. In the ten cases in which the reconstructed area lay within the secondary weight bearing surface hyperkeratosis was entirely absent. Microscopic examination of the border zone verified the clinical findings. Defects in the skin of the heel and the achilles region reconstructed according to the above methods also revealed hyperkeratosis. If a defect is reconstructed within the primary weight bearing surface by means of a skin graft taken from a hair bearing area and if this skin graft is exposed to normal weight bearing then the pigmentation increases, the horny layer becomes thicker and the hair follicles are keratinised. The latter are therefore easily infected and the result is an ulceration which heals poorly with a consequent distressing sore. In order to avoid these complications, defects in the weight bearing surfaces of the foot were reconstructed in Department of Plastic Surgery, Sahlgrenska sjukhuset, with full thickness skin graft from the non hair bearing area of the dorsum of the foot (*Arellan & Johanson* 1963). This site was covered with a split skin graft from a hair bearing area on the lateral side of the thigh. In special cases with acute injury, necrosis or chronic ulceration a preparatory operation was necessary. Here a tem

TABLE 1
Cause and Distribution

	Sole	Heel	Achilles	Total
Laceration	2	2	–	4
Pressure (plaster of Paris)	–	1	3	4
Burn	–	–	1	1
Clavus	12	–	–	1
Innocent Tumor	4	1	–	5
Malignant Tumor	3	1	–	4
Total	21	5	4	30

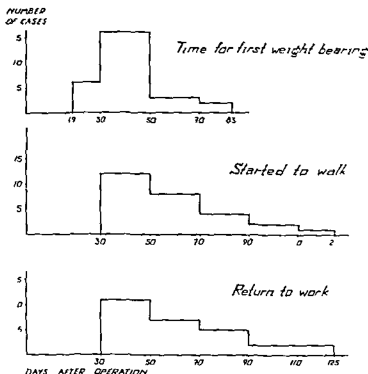


TABLE 2

porary reconstruction of the defect was performed using a split skin graft from a hair bearing area The series comprises 30 cases in all 20 of which are men and 10 women The average age was 31 the youngest patient was 16 the oldest was 66 years The distribution of diagnosis and localisation is shown in Table 1 In 11 cases with lesser defects the full thickness skin graft was taken from the dorsal aspects of the same foot and in the remaining 19 cases from the contralateral dorsum of the foot Treatment at the hospital lasted on average 15 days calculated from the operation to discharge the longest period was 30 days the shortest was 8 days In 28 of the cases the full thickness skin graft healed primarily In two cases the reconstruction led to no result In one of these cases the patient had a malignant melanoma in the sole of the foot in which a more radical intervention was indicated and in the other case the patient had a pressure sore in the achilles region where a preparatory operation had been necessary The times at which the patients began to put weight on the foot to walk and to resume work are shown in Table 2 The longest period of convalescence 125 days occurred in a case with clavus in both *soles of the foot where the operation was bilateral*

Results

The clinical follow up was completed with a pedogram The pedogram gave information about how large a portion of the skin graft lay within the primary weight bearing surface Out of 21 foot sole reconstruction 14 lay 100 per cent within this

area 5 lay 40 per cent and 2 lay 14 per cent within it The full thickness skin grafts of the 28 cases healed well and the scars were soft and fine No hyperkeratosis was encountered in the zone bordering on the intact skin The pigmentation was the same as in the surrounding skin On the other hand the split skin graft on the dorsal foot displayed increased pigmentation Sensibility was examined by discrimination between two points and on average the value 22 6 mm was obtained in the full thickness skin graft as against 18 5 mm in the corresponding area on the other foot The longest period of observation was 4 years the shortest 2½ months or on average 2 years

In conclusion it may be said that full thickness skin graft from the dorsal foot is satisfactory both as to function and appearance when defects in the weight bearing surfaces of the foot and especially in the primary surface of the sole are reconstructed Preoperative analysis of the sole of the foot by pedograph is recommended

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DISCUSSION

Johs Mortens (Copenhagen)

Congratulations to Doctor Avellan for his very valuable information concerning free skin grafting from the dorsum of the foot to the planta which never gives rise to hyperkeratosis in the suture lines

Doctor Avellan s well known colleague from the Mount Vernon Hospital outside London Doctor *Moulem* has shown Doctor Mortens a procedure which Mortens has used with success several times

After excision of a hyperkeratosis area on the primary weight bearing area of the forefoot often in the region of the second or third metatarsal head a local flap from the secondary area distal in the planta at the base of the toes was rotated 90 degrees and advanced to cover the excised area The donor defect could be directly closed by interrupted sutures as the thin skin in this secondary area is very mobile Doctor *Moulem* has used this procedure often and Doctor Mortens has never had hyperkeratosis occurring at the suture lines around the advancement flap

Henrik V A Heikel (Björneborg Finland)

I have had an opportunity of testing the method reported by *Avellan* for a combined crushing and avulsion injury on a foot where an avulsed patch of skin and subcutis comprising the area beneath capituli II V half the lateral edge of the foot and part of the heel planta became necrosed and left a large skin defect In two sessions the defect was covered with skin first from the dorsum of one foot and then from the other dorsum The donor sites were covered with strips of epidermis from the thigh The patient has now walked for 4 months and has worked as tractor driver for 2 months and the transplants have remained intact

TRIPLE ARTHRODESIS AS A TREATMENT FOR POST TRAUMATIC CONDITIONS

by *R Kivilaakso* and *P Salenius* (Helsingfors)

The material includes all patients who from July 1956 to June 1963 were treated by triple arthrodesis for post traumatic conditions at the Orthopaedic Hospital of the Invalid Foundation Helsinki This made a total of 32 patients of whom 24 were men and 8 women The youngest patient was aged 15 and the oldest 62 The dominant indication for the operation was pain caused either by arthrosis in the subtalar joint or in young patients by displacement or deformity in itself

Arthrodesis was performed by removing articular cartilage from the talo calcaneal talo navicular and calcaneo cuboidal joints after which the bone surfaces were pressed together

The time of immobilization in plaster was in all cases 4 months During the first month no weight bearing was allowed but during the following three months full weight bearing was ordered in a walking plaster

Re examination was carried out at the beginning of 1964 In one case the Chopart joint remained unossified and the patient complained of pain In all other cases ossification was complete In 26 cases the result was good both subjectively and objectively

All 26 in whom the results of treatment were good in every respect continued after re examination the work they had been doing before the operation Of the 6 in whom weight bearing caused pain 5 also returned to their former work

RESULTS AFTER AMPUTATIONS OF CHOPART PIROGOFF AND SYME

by *Castor Lindqvist* and *Erik B Riska* (Helsingfors)

Foot amputations are seldom taken into consideration in cases of foot injury Perhaps below knee amputation is far too often preferred to surgery at the ankle level or they are treated conservatively in order to preserve as much as possible Recent development in biophysics and prosthetics however have stimulated interest in stumps of Chopart Pirogoff and Syme

Since 1960 25 patients were fitted with prostheses of plastic laminate by the Proesthetic Shop of the Orthopaedic Hospital of the Invalid Foundation in Helsinki 19 patients were available for follow up examination in the spring of 1964 5 cases of Chopart 4 cases of Pirogoff (or Boyd) and 10 cases of Syme The number of stumps was 21 because of two double amputees

Attention was primarily paid to the condition of the stump Results are sum

TABLE 1
Results of Surgery

Amputation stump	Syme No of cases	Pirogoff or Boyd No of cases	Chopart No of cases
Good	8	4	3
Fair	2		1
Poor	1		-
Total	11	4	6

marized in Table 1 Secondly the function of prosthesis was investigated Functional results are given in Table 2

TABLE 2
Functional Results

Function of stump and prosthesis	Syme No of cases	Pirogoff or Boyd No of cases	Chopart No of cases
Good	9	4	2
Fair	2		1
Poor			3
Total	11	4	6

Conclusions

1 Amputation of Syme generally results in a reliable stump which is now days easy to fit with a functional prosthesis

2 Amputation of Pirogoff (or Boyd) seems to result in a stump comparable with that of Syme Deficient ossification between os calcis and tibia however is a potential risk even if it was not the case in any of the stumps examined

3 Amputation of Chopart easily results in stumps with a great variety of discomfort and it is problematic to fit them with a prosthesis

BRIEF PAPERS

RESULTS OF SURGERY ON PSEUDARTHROSES IN THE LONG BONES

by *Sv Rosendahl* and *K Bødsgård Sørensen* (Copenhagen)

The results of 120 operations on 96 pseudarthroses done in the Orthopaedic Hospital Copenhagen during the period 1952 1962 were reported

The site was the humerus in 12 cases the radius in 10 the ulna in 14 the femur in 19 and the lower leg in 41 Healing after the first operation was obtained in 69 8 per cent A total of 88 5 per cent had healed in 4–24 months average 7 months There was no difference in the healing rate by site Out of the 11 non healed cases 4 later had amputation because of infection and 7 were fitted with bandages after having refused to have re-operation Two thirds of the fractures were sustained in traffic accidents and two thirds had been treated primarily by osteosynthesis There was no difference in the healing rate in the different age groups but the healing tendency was best in the cases where pseudarthrosis was of shortest duration Nevertheless healing occurred in 6 per cent of the cases of more than 2 years duration

After treatment with grafts of cortical bone 656 per cent—79 per cent healed with the onlay and 56 per cent with the inlay technique

After treatment with grafts of spongy bone 78 per cent—90 per cent healed with the onlay and 70 per cent with the inlay technique

Of the cases treated with internal fixation or with resection of the pseudarthrosis 63 per cent healed

In other words the highest healing rate was found after onlay grafts of spongy bone Resection of the pseudarthrosis and internal fixation did not improve the healing tendency

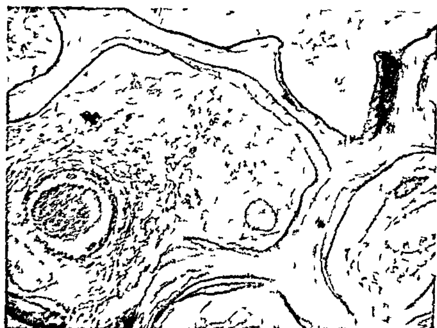


Fig 1

NECROSIS OF THE FEMORAL HEAD AFTER FRACTURE OF THE NECK OF THE FEMUR

by H Bohr and F Hjalmar Larsen (Publ in the British Volume of the Journal of Bone and Joint Surgery)

The scleroses of the head of the femur which may be seen on the radiograph following fractures of femoral neck is generally interpreted as a sign of necrosis In certain cases it is merely a question of relative increased density compared with osteoporosis of the surrounding bones but in cases having absolute sclerosis with increased density of the bone it was previously believed that the necrotic bone had taken up further calcium as does necrotic tissue in other sites Recently however it has been pointed out by several authors that sclerosis may be caused by apposition of newformed bone to necrotic bony lamellae

In order to elucidate this aspect the present authors performed microradiographic *and histological studies on the femoral heads from patients admitted to* the Orthopaedic Hospital Copenhagen for arthroplastic operations of the hip A total of 24 specimens were studied 7 from patients who had been operated 1 30 days and 17 from patients who had been operated 30 days—5 years after the fracture

Determination of the degree of mineralization by quantitative microradiography revealed no significant differences while the width of the bony lamellae was distinctly increased in cases where X rays showed sclerosis

The histological studies disclosed that the increase in the width of the bony lamellae was due to apposition of newformed living bony tissue on the surface of the necrotic bony lamellae as seen from the figure

It is concluded that although sclerosis observed on the radiograph is a result of

necrosis it is at the same time a definite sign that revascularization and restitution processes are taking place In reporting the total series the authors described details of the different phases o this process

OSTEOSYNTHESIS WITH RADIOLOGICAL TELEVISION IN TWO PLANES

by *S Ahlback B Broden* and *M Fellander* (St Goran s Hospital Stockholm)

The method has been employed in fractures of the femoral neck and in diaphyseal fractures of the femur and tibia

Two closed medical TV circuits have been used, one for vertical and the other for horizontal ray direction The roentgen and intensifier tubes are independent of one another In order that distance and centering may be freely selected We have used a special extension table on which we have been able to suspend the frontal image intesifier so that it follows the movements of the table *e g* in the Trendelenburg position The projections are identical with those used in conventional roentgen examinations In lateral projection of the femoral neck, the front of the intensifier tube is inserted above the iliac crest as far as soft tissues allow Despite the fact that we use an intensifier tube of a dimension as large as 9 inches the surgeon s freedom of movement is not infringed upon The lateral view is an especially difficult projection In order to decrease the thickness of the object we use a harness which is attached to the table on the side of the fracture running around the uppermost part of the thigh and flattening the soft tissues over the femoral neck and caput During extension the harness provides an equally efficient counter check as a perineal post and can completely replace it We have used the smallest possible aperture combined with high clean up grids which is essential for the quality of the image

An important advantage of the method is that the equipment can remain immobile during the entire operation It contains no stages which disrupt the operation such as cassette changes or adjustments of the position of the equipment The possibility of simultaneous screening in two planes or instantaneous shifting from frontal to lateral view saves time and gives greater exactness Space around the field of operation is more ample than when an arc unit is used Furthermore as the equipment is immobile sterility is not endangered

The method makes continuous checking of reduction possible and the repositioning maneuvers may be efficiently conducted In fractures of the femoral neck the tip point of entrance and direction of the guide may be determined immediately The position of the point of the nail can be selected with a tolerance of a few millimeters which is important in cases with a small caput fragment

In diaphyseal fractures which are fixated through intramedullary nailing the fracture need not be exposed which should eliminate risk of infection and a possible deterioration in the healing proces brought about by exposure

The operating time especiall in fractures of the femoral neck, is considerably briefer than when the nailing is controlled through conventional radiologs

The roentgen dosage during the nailing of a femoral neck fracture is definitely below 10 milliroentgen for the surgeon and below 5 milliroentgen for other staff

65 operations of feemoral neck fractures and 10 operations of diaphyseal fractures have been performed in accordance with the technique described above

The lecture was illustrated by a video tape recording of televised images in both planes during a nailing of a femoral neck fracture

PRELIMINARY REPORT ON THE CLINICAL TESTING OF TITANIUM

by *Hans Eneus* and *Gudmunder Gudmundsson* (Lund Sweden)

For 3 years Tupman s nail and plate have been used in the fixation of osteotomies Stainless steel and titanium were employed successively and in strict alternation throughout these operations

During the same period arthroplastics according to *Moore* were performed and in strict succession vitallium prosthesis alternated with tianium prosthesis 50 osteotomies and 50 Moore plastics make up the series We consider therefore that we possess a clear idea of the mechanical and chemical qualities of titanium when compared with current material

On preliminary review titanium seems capable of use for hip prostheses in the same way as vitallium Titanium can be used as osteosynthesis material but has certain disadvantages by comparison with steel After one has become accustomed to its special qualities one can work very well with it

Titanium s chemistry in living tissue has not yet been elucidated The tissue is sometimes blackened by the titanium applications The black pigment consists of titanium which has been shown to be present both qualitatively and quantitatively It is not yet possible to show in what form the titanium appears in the pigment It is extremely interesting that the titanium osteosynthesis material adheres the tissue and that in spite of abundant manifestation in both phagocytic and non phagocytic form it does not cause any tissue reaction

THE GAIT WITH AN ANKYLOSED HIP

by *M Foss Hauge* (Oslo)

A short survey is given of the movements of the pelvis in patients with a unilateral ankylotic hip

The most normal gait—and at the same time the most satisfactory from an aesthetic point of view—is achieved by the following position of the hip

15 degrees of flexion
3– 5 degrees of *ad*duction
5–10 degrees of external rotation

REHABILITATION OF THE AGED AFTER AMPUTATION

by *Ralf Lindholm* (Vasa Finland)

The development in geriatric care demands increased effort to satisfy among other things the special requirements of rehabilitation which arise in connexion with amputation surgery

The majority of rehabilitation centres present statistical samples which obviously

The degrees refer to the method of measuring joint motion recently advocated by the American Academy of Orthopaedic Surgeons



Fig 1

represent a selected group The attitude towards prognosis shows a high degree of variation The most optimistic centres completely neglect the quota of primary patients assigned to long term care beyond the reach of rehabilitation facilities It is therefore not possible to obtain a complete picture of the situation This series includes 86 patients above 65 years of age who underwent amputation in a geriatric unit (Koskela/Forsby Geriatric Hospital Helsinki/Helsingfors) with departments of internal medicine surgery and psychiatry and with related departments of rehabilitation and physiotherapy The series comprise all 1961–63 patients in the institution as lower extremity amputees registered the majority underwent the operative stage at the same hospital The amputation indication was almost without exception peripheral vascular gangrene

Within six months after the operation 30 5 per cent of all those amputated had died An observation which seems to give cause for considerable scepticism and reserve when evaluating the post operative prognosis

At the follow up 15 1 per cent of the patients were walking 26 7 per cent were confined to a wheel chair with satisfactory activities of daily living 11 6 per cent were bedridden and 41 5 per cent had passed away The last figure merely indicates a minimum mortality with 2½ years after operation In many cases the observation period was much shorter

The prognosis is clear in relation to the level of amputation (Table 1) and to the age (Table 2)

The principle of using a temporary prosthesis during training and as a test method seems to justify its purpose Experience with this series confirms that the amputees accept the test method

81 per cent of the amputees were found to be independent of institutional care and did not require aid socially.

The ability to walk learnt when young seems to remain throughout life while even those in old age amputated patients who are somatically well equipped are not always able to adjust themselves to the new biomechanical situation of walking with a prosthesis.

Prosthesis training of geriatric amputees is if anything a team exercise and demands considerable institutional resources and expertise in orthopaedics, physiotherapy, occupational therapy, prosthesis maintenance and social care.

TABLE 1

Type of Amputation and Result of Rehabilitation in 46 Surviving Geriatric Amputated Patients

Type	No. of patients			
	Walking	In wheelchair	In bed	Total
unilateral thigh	5	14	7	26
unilateral lower leg	8	1	1	10
bilateral thigh		6	2	8
bilateral thigh + lower leg	–	2	–	2
	13	23	10	46

TABLE 2

Age and Rehabilitation Result

Age year	No. of patients				
	Walking	In wheelchair	In bed	Dead within 2 yrs	Total
65 – 69	7	8	1	4	0
70 – 79	4	10	4	16	34
80 – 89	2	5	5	18	30
90 –		–	–	2	2
over 65	13	23	10	40	86

OXYTETRACYCLINE LABELLING OF BONE IN EXPERIMENTAL AFFECTIONS OF THE HIP JOINT

by P. Rokkanen, I. Slätis and H. Laine (Helsingfors)

The value of tetracycline labelling of bone has been estimated by comparison with histologic and roentgenologic findings in experiments on the hip joint. In 39 rabbits the following operations were carried out. In 15 animals the left hip joint was opened, the femoral head exarticulated and the lig. teres severed. In addition to this the femoral neck was tightly ligated in all animals. In another 24 animals a subcapital total osteotomy of the femoral neck was performed, in 12 with out severance

of the lig teres The right hip served as a control Oxytetracycline was administered on three consecutive days prior to death The time interval between operation and death varied from 1 week to 22 months

Oxytetracycline fluorescence in the femoral head and neck, as observed macroscopically or in the UV microscope was compared with the histologic and roentgenologic findings Special interest was focused on aseptic necrosis and regenerative phenomena Histologicall dead areas showed no fluorescence whereas regenerative invasion of connective tissue and new bone was accompanied by intensive patchy fluorscence The fluorescence phenomenon was easily recognized and the labelled tissues well defined The viability of the cancellous bone seemed to be more accurately re ealed by the fluorescence technique than by ordinary histologic methods

To be published in Acta Orthopaedica Scandinavica

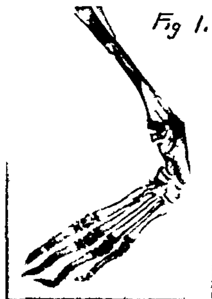
EXPERIMENTAL FOOT DEFORMITIES

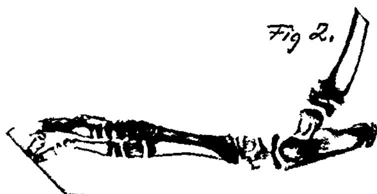
by *Veijo Ritsilä* (Helsingfors)

In order to provoke phenotypically deformities resembling congenital foot deformities various operations were performed on the leg muscles and ligaments of young rabbits Immobilizations in plaster were also performed

Results were based on experiments performed on about 400 young rabbits Some dozens of combined operations on muscles and tendons were performed Many phenocopies of foot deformities occurring in human beings were successfully provoked

The most interesting results were obtained in pes equinovarus and talus verticalis deformities whose changes both anatomically and radiologically corresponded fully with the changes encountered in clinical material





Pes equinovarus deformity (Fig 1) was achieved only in the following combination of 3 components

First the proximal part of the Achilles tendon was fixed through a hole bored halfway through the tibia diaphysis Tenodesis was thus performed

Second discission of peroneal muscles and musculus extensor digitorum longus was performed Pronation effect was thus eliminated

Third musculus tibialis anterior musculus tibialis posterior and musculus flexor digitorum longs and therefore supination effect were left intact

In addition by immobilizing the foot in plaster in the equinovarus and adductus position a permanent club foot was obtained with an immobilization time of 3-4 weeks

A deformity corresponding to congenital talus verticalis (Fig 2) was obtained by performing discission of ligamentum transversum cruris and the Achilles tendon fixation described above Talus verticalis also developed if either musculus extensor digitorum longus or musculus tibialis anterior was discided simultaneously with the previous operation The deformities thus obtained differed from each other with regard to supination and pronation It was possible to differentiate both types al in clinical material

In later experiments talus verticalis was also obtained by provoking in another way contractures in either musculus tibialis anterior or musculus digitorum longus and simultaneously in triceps surae

ON THE CLOSED AND OPEN CORRECTION OF CONGENITAL CONVEX PES VALGUS WITH A VERTICAL ASTRAGALUS

by *H Storen* (Oslo)

In the title of this paper the author had added with vertical astragalus to the American designation congenital convex pes valgus" because without this addition the term is misleading The fact is that a congenital convex pes valgus may also exist *without* a vertical astragalus and it may be of the same appearance and show the same degree of contracture

An extremely important difference between these two conditions is that in a n



Fig 1

genital convex pes valgus *with* vertical astragalus there is a dorsal dislocation or subluxation in Chopart's joint in which abnormal dorsal flexion occurs so that clinically the appearance is as in congenital pes *calcaneo* valgus X rays are required to make the differential diagnosis —which may be made already at birth

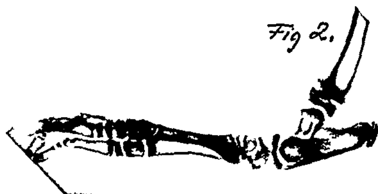
Fig 1 shows the X ray appearances in a 4 day old baby with vertical astragalus In 1934 *Hohman* gave a detailed description of this abnormality which he called der angeborne Knickplattfuss" He reported good results of closed correction when it was started within the first week of life He applied a plaster cast until the infants started walking But closed correction is not always successful even when started at an early age as is apparent from *Cün s* (1939) autopsy finding in a still born infant Merely the cutting of the extensor tendons and ligaments effected the reduction in this case

At the Scandinavian Orthopaedic Congress in Copenhagen in 1962 *Wainwright* submitted good results in 8 cases treated by closed correction

On the other hand there are American orthopaedic surgeons e g *Herndon* and *Heyman* who claim that radiologically demonstrable correction can be obtained only by open reduction

Cric claim that it is only in very mild cases that real cure is obtainable by closed correction and that open reduction is needed They all claim that any case has to be operated upon as it has been diagnosed before irreversible changes have developed

German as well as American orthopaedic surgeons have pointed out that "congenital convex valgus with vertical astragalus" cannot be considered on an equal footing with secondary vertical position of the astragalus which may be seen in



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An extremely important difference between these two conditions is that in con

3) Ligamentum talocolcaneare interosseum This ligament counteracts the reduction of the laterally displaced calcaneus and its valgus position
4) Ligamentum calcaneocuboid counteracts the reduction of the abducted position of Chopart s joint (Often it is not necessary to cut this ligament)

When these ligaments have been cut—or in closed correction sufficiently stretched—the reduction is successful Obviously this stretching is the more effective the shorter the period after birth it is carried out

What influence does reduction of the dorsal dislocation of the forefoot exert upon the vertical position of the astragalus?

It has been found that in a lot of cases the astragalus assumes its correct position when the dislocation has been abolished It would seem as if the vertical position of the astragalus were secondary—as it is the dorsally dislocated forefoot which presses the astragalus down into the vertical position Fig 3 a illustrates a Rockybottom foot with vertical astragalus It was reduced by the closed technique and had remained reduced for more than one year (cf Fig 3 b which shows the normal horizontal position of the astragalus) Then an acute re dislocation occurred after an incautious passive dorsal flexion of the forefoot (Fig 3 c) Note how the astragalus from the horizontal position has risen into the vertical position

In my series the cases in which the astragalus has not assumed its correct position were elderly patients who apart from shrinkage of tibio astragalar posterior ligaments as in inveterated cases of pes equinovarus may be imagined to have developed secondary narrowing of the anterior part of the ankle joint



Fig 3 A
Anne C H Before reduction at 3½ months of age

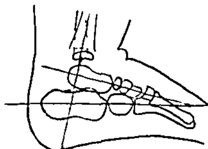


Fig 3 B
Anne C H One year after closed reduction Maximal dorsiflexion
The tibia talus angle is normal

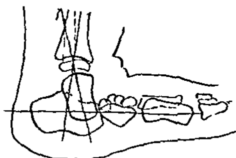


Fig 3 C

Anne C H One year later after redislocation the talus is pressed downwards in a vertical position

Lengthening of the Achilles tendon in cases which I have had occasion to assess critically appears to have had little or no effect upon the correction of the astragalus Such lengthening has not been necessary in my cases—neither in those treated by open nor by closed reduction

In one case in which I believed that it was necessitated by the equinus position of the calcaneus—I performed primary lenthening However it proved unnecessary if not unfortunate

But it is not only the correction but a permanent retention of the obtained position which poses a problem Operation reveals dorsal flattening of the head and neck of the astragalus due to the pressure which the dorsally dislocated scaphoid bone has exerted upon this site This is the more pronounced the older the child After the reduction then the scaphoid bone lacks sufficient support and is apt to slide upwards This is observed during the operation as well as later

TABLE 1

Tabulation of Results

Closed correction

Case	Age at commencement of treatment	Age at last follow up	Results
Moderate 3 feet	3 14 days	3 6 years	Complete cure
Severe 2 feet	4 days 6 months	3 years	(1) Complete cure (2) Acute recurrence at end of 1 year Treatm continued
		Open correction	
Severe 5 feet	16 months 5 years	8 12 years	Complet correction Vertical position abolished

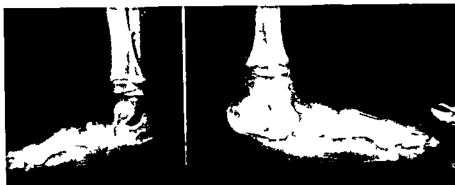


Fig 4 A
X ray appearance before operation



Fig 4 B
7 months after the operation



Fig 5 A
10 years after the operation

As mentioned by *Hohman* and *Spitzy* the critical period occurs when the baby starts walking When the foot leaves the floor Chopart's joint becomes dorsally flexed with pressure beneath the forefoot In order to prevent this action child should wear a high heeled shoe in which the sole is built so that the calcaneus is in a horizontal position and the forefoot in plantar flexion



Fig 5 B
Clinical appearances 10 years after the operation The arch of the foot is excavated but without causing any complaint keen on sport No complaints

For lack of time I shall report here only the case with the longest follow up a patient who had bilateral operation at the age of 16 months and has been followed for 10 years The Achilles tendon was not lenghtened

Conclusion

Accordingly the treatment of congenital convex pes valgus with vertical astragalus should be as follows

All suspected cases should be X rayed immediately If the astragalus is vertical closed correction should be performed at once If this procedure is not successful after one or more attemps open correction should be done Fixation in plaster cast until weight bearing starts High heeled shoe for a year or so The patient should be X rayed on all follow up visits even though the position appears to be clinically satisfactory

NORMAL REPAIR OF FRACTURES OF THE LONG BONES A HISTO QUANTITATIVE STUDY

by *P Rokkanen I Slätis* and *H Laine* (Helsingfors)

Normal repair of closed experimental fractures of the lower leg was investigated *in 60 adult white rats by histologic and roentgenologic methods up* to 6 months following the fracture The composition of the callus tissue was quantitatively analyzed from the histologic specimens by means of the linesampling method The area of the roentgenologically visible callus was measured by planimetry of the roentgenographs

Deposition of new bone in the periosteal collar far away from the broken bone ends can be detected as early as 6 days after the fracture Cartilage and connective tissue however quantitatively dominate the callus (53 71 per cent) during the first 4 weeks of repair After this the amount of new bone correspondingly increases to a maximum (62 per cent) 12 weeks after the fracture The area of roentgenologically visible callus reaches a maximum about 8 weeks after the fracture

To be published in Acta Orthopaedica Scandinavica

DISCUSSION

H Heikel (Bjornel org Finlan l)

It is surprising that such good results have been achieved in epiphysis trans plantation with such old test animals of Mr *Ry ppy* partially used In my own experiments I thought that I found the capacity f r growth in lengst to be less in lder than in very young animals in which the ossification of the epiphyseal nucleus was only just beginning or had not yet begun When the transplant is inserted into a defect in a long bone whi h is connected at both ends (by ossification or by ligament) with antother bone (such as fibula and tibia) it cannot be excluded that continued growth of the latter bone may produce a stretching of the transplant and that the observe l increa e in length cannot l e definitely interpreted as true growth

ARTHRODESIS CARPI

by *P Salenius* (Helsingfors)

At the Orthopaedic Hospital of the Invalid Foun lation Helsinki in the period 1945–1963 arthrodesis of the wrist was performed in 42 cases Of these patients 35 were men and 7 women The youngest patient was aged 14 the oldest 56

The Brittain method was used in most cases but in some the method was modified by fixing the graft with screws Five patients were operated upon without a tibial graft

Among those treated by the Brittain method a fracture occurred in the graft in four cases and fibrous union in three cases Five of these cases were re operated with good consoli lation as a result Two patients had a fracture of the tibia from which the graft was taken

39 of the patients were re-examined in 1963 and 1964 In 37 cases the treatment had le l to l ony anchylosis in the wrist One patient had a clear pseudarthrosis in the operation area in anotheer patient the treatment had led to fibrous union

Objective results were good in 26 cases satisfactory in 11 and poor in 2

Results on re examination according to the patients estimation were good in 31 cases atisfactory in 6 and poor in 2

COMPLICATIONS OF AND ERRONEOUS INDICATIONS FOR LOCAL TREATMENT WITH CORTICOSTEROIDS

by *I is Zacharae* (Copenhagen)

Upon systemic a well as topical administration cortisone preparations inhibit the newformation of connective tissue acting upon all components of the connective ti sue Clinically this effect is antiinflammatory antioedematous antiallergic and analgesic

The complicati ns of local treatment are infecti n and degenerati e changes A number of slides illustrated these facts Particular importance is attached to the finding that local treatment with corticosteroids in cases of osteoarthritis ma be f llowed by considerable ra iologically demonstrable exacerl ation

The various theories advanced concerning this exacerbation of osteoarthritis during corticosteroid therapy were mentioned i e traumatic spontaneous progression of the original disease or a Charcot like mechanism i e the joint being worn because it has been rendered painless by the treatment

In the author s opinion none of these theories is satisfactory It is suggested that cortisone therapy inhibits the regeneration which must always go on in the tissues so that degenerative processes predominate

Finally it is pointed out that cortisone preparations should only be used in diseases in which the above mentioned special effects are desired For instance local treatment with cortisone preparations should be considered contra indicated in diseases such as osteochondritis Schlatter s disease and the like in which regeneration of the tissue is desired

The following conclusions are drawn

1) On local administration corticosteroids have fundamentally the same effect upon mesenchymal tissues as when administered systemically

2) The corticosteroids inhibit the newformation of connective tissue they have an antiinflammatory antioedematous antiallergic analgesic and possibly also a specific effect upon joints

3) These actions may in certain cases have a therapeutic effect while in other cases they may give rise to degeneration and necrosis of the tissues

4) Locally administered cortisone preparations are to some extent absorbed in the organism but rarely to the extent of giving rise to systemic side effects

5) Infection is also an important complication

6) There is an indication for therapeutic use of corticosteroid preparations only in diseases in which an antiinflammatory effect or an inhibition of connective tissue newformation is desired

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From the Hospital for Special Surgery affiliated with The New York Hospital—Cornell University Medical College supported by AEC Grant—Contract AT (30-1) 3234 and Easter Seal Research Foundation

THE EFFECT OF MOTOR DENERVATION ON MUSCLE AND BONE IN THE RABBIT S HIND LIMB

By

OVED KHARMOSH[1] and PAUL D SAVILLE*

Motor denervation of a limb leads to atrophy of both muscle and bone Neither the mechanisms by which this occurs nor the relationship between muscle and bone atrophy are well understood *Gillespie* (1954) found a positive correlation between the weight of bone of a paralyzed limb and the weight of the whole skinned limb He concluded that bone atrophy was due to loss of muscular activity Since the chronological sequence of changes in muscles and bones following motor denervation has not been studied we undertook to quantitate these changes and by using calcium 47 further to clarify the bone changes

MATERIALS AND METHODS

Four month-old male Chinchilla rabbits averaging two kilogram in weight were kept in individual cages They consumed about 150 grams daily of Ralston Purina pellets enriched with vitamins A and D Under Sedosal anesthesia supplemented by one half per cent novocain locally left hemilaminectomy of L6 and 7 with unroofing of the upper segment of the sacral canal was performed. The spinal cord and the sixth and seventh lumbar and first sacral nerve roots were exposed (Fig 1) The dura on the lateral aspect of the spinal cord was incised Under magnification the anterior nerve roots were brought to view from under the cord with a nerve hook and sectioned Severe bleeding which proved to be a major problem was reduced by partially suspending the animal from towel clips inserted into a spinous process

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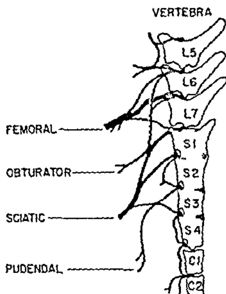


Fig 1

The lumbosacral plexus from The Rabbit in Experimental Physiology by Harold M Kaplan reproduced with the permission of the Scholar s Library New York

so as to remove pressure from the abdomen The operating field was kept dry by suction Blood loss estimated at twenty to thirty milliliters was replaced by injection of saline On recovery from operation the paralyzed limb was dragged behind the animal during locomotion and hung down motionless and toneless in contrast to the non paralyzed right limb when the rabbit was suspended from the skin of the neck

Post operative mortality was twenty five per cent It was noted that none of the animals had gained weight during the experiment The rabbits were sacrificed in four groups at ten days four to six weeks eight to ten weeks and twelve to fourteen weeks respectively Twenty four hours before sacrifice each rabbit was intravenously injected with about five microcuries of Ca-47 as CaCl with a specific activity of 150 millicuries per gram of calcium After death the animals were weighed and the hind legs skinned and disarticulated at the hip joint Following disarticulation the skinned limb was weighed and the muscle and soft tissues were cleaned off the bone The cleaned bone was suspended by fine copper wire in distilled water degassed in a vacuum chamber for half an hour at five to seven millimeters Hg and reweighed The volume and density of the bone were then calculated by Archimedes Principle The bones were ashed in a muffle furnace at 600 overnight and weighed The ash was dissolved in 2N HCl and made up to volume in a volumetric flask Aliquots of this ash together with a standard were counted in a well counter with appropriate adjustments of the base level and window to exclude Sc-47 Results were expressed as fraction of dose per gram of ash Bone ash weights and muscle weights in the paralyzed limbs were expressed as a fraction of the control limb

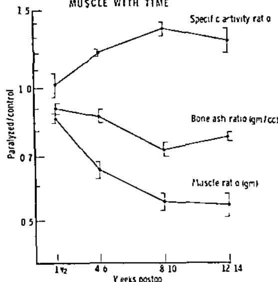


Fig 2

Muscle weight bone ash weight and specific activity in the paralyzed limbs are expressed as a fraction of control and plotted against time after operation

RESULTS

Significant muscle atrophy was evident by the tenth day post operatively and progressed steadily until the tenth week when the weight of the muscles on the paralyzed side averaged 55 per cent of the control side. There was no further loss of weight until the end of the experiment at fourteen weeks (Fig 2 Table 1)

TABLE 1

Effect of Motor Denervation on Bone and Muscle with Time

No of Animals	Duration of Paralysis (wks)	Muscle Mass per cent of Control $\bar{x}$ $S\bar{x}$	Femur and Tibia Ash Weight per cent of Control x $S\bar{x}$	CPM/C Ash per cent of Control x $S\bar{x}$
5	1 5	85.2 ± 2 6	90 2 ± 2 53	102 ± 6 7
14	4 6	65.2 ± 2 9	86 6 ± 3 0	120 ± 2.3
12	8–10	55.2 ± 2 5	72 6 ± 2 6	136 ± 4 7
7	12 14	54.2 ± 3.3	7.5 ± 1 77	128 ± 8 2

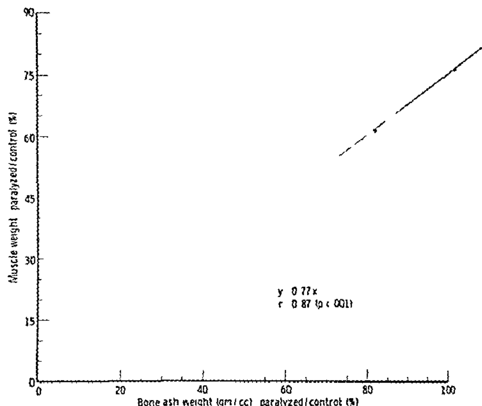


Fig 3

Muscle weight on the paralyzed side expressed as a percentage of control plotted against bone a h weight on the paralyzed side expressed as a percentage of control Since the calculated intercept of the regression was not significantly different fr m zero the regression line was drawn through the origin

Bone atrophy showed the same trend as muscle atrophy but was less pronounced The bone ash weight of the paralyzed side in animals killed ten days post operatively averaged 90 per cent of the control side (this was highly significant $P < 001$) The bone ash weight on the paralyzed side of the four to six week group averaged 86 per cent of control side (not significantly different from the ten day group $5 < P < 6$) Bone ash weight of paralyzed side in the eight to ten week group aver iged 72 per cent of the control (significantly different from the four to six week group $P < 01$) There was no significant difference in bone ash weight on the paralyzed side between the animal killed between eight and ten weeks and those killed between twelve to fourteen weeks ($7 < P < 8$) Correlation between bone and muscle atrophy was highly significant $r = 87$ $P < 001$ The formula for the

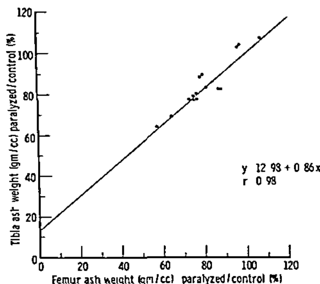


Fig 4

Tibia ash weight on the paralyzed side is expressed as a percentage of control and plotted against femur ash weight as a percentage of control The coefficient of correlation and the equation for the regression line are given

regression of muscle atrophy on bone atrophy was Y = 77X where Y was the weight of muscle from the paralyzed side expressed as a fraction of the control side and X was the weight of bone ash on the paralyzed side expressed as a fraction of the control side (Fig 3) The regression of bone ash weight on the paralyzed side expressed as a percentage of bone ash weight on the control side was graphed for tibiae against femora (Fig 4) r = 98 P < 001 The equation used in correlating femur and tibia ash loss was Y = 12 98 + 0 86X

Fig 5 shows the regression of total radioactivity in the bone ash of the paralyzed side compared with the control side against the weight of bone ash on the paralyzed side as a percentage of the control side r = 65 P < 001 As the amount of ash decreased so did the total radioactivity Y = 28 + 0 009X In Fig 6 the specific activity in the bone ash on the paralyzed side (Y) was plotted against that on the control side (X) The regression is given by the equation Y = 1 34 X Fig 2 and Table 1 show the specific activity ratios between the operated and control bones in the four groups throughout the experiment Ten days post operatively the ratio was 1 00 at four to six weeks the ratio was 1 20 at eight to ten weeks 1 36 and twelve to fourteen

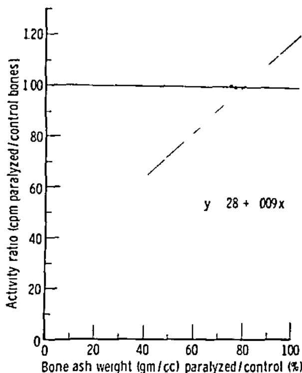


Fig 5

Radioactivity in the bone ash of the paralyzed side is expressed as a fraction of control and plotted against bone ash on the paralyzed side expressed as a percentage of control

weeks 1 28 The difference between the first and second groups was significant ($P < 05$) The difference between the four to six week and the eight to ten week groups was significant ($P < 02$) There was no statistical difference between the eight to ten week and the twelve to fourteen week groups ($P > 2$)

DISCUSSION

Armstrong (1946) measuring bone ash weight showed that the percentage difference between the two limbs in normal rats is statistically insignificant *Slack* (1954) showed that there is less than two percent difference in weight of the left and right normal hind limbs of rats and concluded that muscle wasting could be most conveniently expressed as a percentage of the control limb *Bohr & Sorensen* (1950) showed that there is equal radioactive uptake in the right and left femurs of

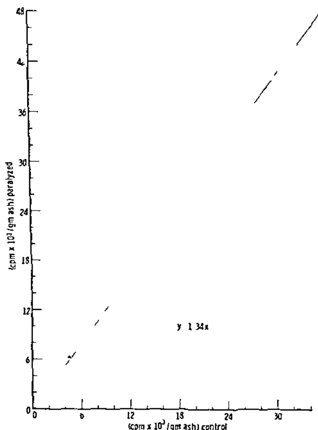


Fig 6

Specific activity in bone ash on the paralyzed side is plotted against specific activity in bone ash on the control side The equation for the regression line is given

rabbits These findings seemed to justify the use of the right normal limb as a control for the left paralyzed one The results show that muscle atrophy begins immediately after motor denervation and continues for ten weeks after which it stops Bone atrophy also is significant at ten days and then continues but to a lesser degree as long as muscle atrophy is going on This finding together with the high correlation between muscle loss and bone ash loss in a paralyzed limb suggests that muscle atrophy determines the extent of bone ash loss *Gillespie* (1954) found a similar correlation in his denervated rabbits *Geiser & Trueta* (1958) sectioned the Achilles tendon or immobilized rabbit hind limbs and concluded that lack of muscular action is the most important factor in inducing loss of bone

If bone ash loss is proportional to the extent of muscle paralysis providing there is complete motor denervation the extent of paralysis in both the thigh and the leg muscles would be expected to be equal and atrophy of femur and tibia would be similar Fig 4 demonstrates that there is a high correlation between bone ash loss in the femora and the tibiae in the paralyzed limbs but that atrophy in the tibia is greater than that in the femur and starts earlier implying more complete denervation of the distal muscles

Heaney (1962) studied accretion rates in patients suffering from acute poliomyelitis He found a higher accretion rate in disuse osteoporosis than in controls *Wendeberg* (1961) in his studies of isotope uptake in fracture of the tibia in man showed that the accretion rate increased both at the fracture site and in the adjacent limb bones as well These patients were immobilized in plaster casts for many weeks following their fractures These findings are in agreement with our own observations of a higher activity ratio in the paralyzed limbs compared with the controls moreover we had the benefit of ashing the bones and measuring directly the specific activity Fig 5 shows that the activity per bone is related to the amount of bone ash When bone ash decreases below eighty per cent of control the total radioactivity is less in the atrophic bones although the specific activity is higher The implication is *that if there were considerable bone atrophy external* counting would show a lower count in the paralyzed limb compared with the control even though the accretion rate was higher on the paralyzed side as it is in our animals The data suggest that bone formation rate is higher during motor denervation Since we know that bone atrophy is occurring at this time it follows that bone resorption must be higher still These findings amplify and confirm the emerging concept that whether bone formation may be normal or higher than normal in localized or generalized osteoporosis increased bone resorption is the dominating mechanism that results in bone atrophy *Bauer* (1964) *Heaney* (1964) *Nordin et al* (1963) *Dymling* (1964) *Eisenberg & Gordan* (1961) *Frost* (1963) Moreover although statistically significant bone atrophy has occurred by ten days the accretion rate has not yet changed The latter rises appreciably at three to four weeks reaching a maximum value at eight to ten weeks and remains constant thereafter It may be inferred that increased bone resorption starts almost immediately after motor denervation and is followed about *three weeks later by a progressive increase in accretion rate* until at ten weeks accretion and resorption have reached a new steady state

and are equal It is apparent that normal bone mass is only partly dependent on muscle function This is consistent with clinical findings that osteoporosis is usually found soon after a limb is immobilized but does not usually progress indefinitely

SUMMARY

Unilateral motor denervation of rabbit hind limbs was performed via hemilaminectomy The muscle weight and bone ash weight on the paralyzed side was expressed as a fraction of that on the control side Total radioactivity as well as specific activity ratios of bone ash were also determined

Muscle and bone atrophy started immediately continued for ten weeks and then stopped Bone accretion did not change until sometime between ten days and four weeks when it increased by about thirty per cent

The findings suggest that muscle atrophy leads to bone atrophy The mechanism of the latter is by increased bone resorption followed by increased accretion until equilibrium is reached and the atrophy stops

RESUME

Une dénervation motrice unilaterale des membres posterieure chez les lapins a ete pratiquee par hemilaminectomie Le poids du muscle et de la cendre de l os du coté de controle La radioactivite totale aussi bien que le rapport de l activite specifique de la cendre de l os ont egalement ete determinés

L atrophie du muscle et de l os fut observee immediatement Elle continua pendant dix semaines et s arreta L accretion de l os n a pas changé entre approximativement 10 jours et 4 semaines ou elle a augmente d environ 30 pour cent

Ces trouvailles suggèrent que l atrophie du muscle mene a l atrophie de l os Le mecanisme de cette derniere est suivi en cas de resorption accrue de l os par une accretion accrue jusqu a ce que l equilibre soit atteint et que l atrophie s arrete

ZUSAMMENFASSUNG

Einseitige motorische Denervation der ruckwartigen Gliedmassen von Kaninchen wurde auf dem Wege einer halbseitigen Laminektomie ausgefuhrt Das Muskelgewicht und Knochenaschegewicht der gelahm

If bone ash loss is proportional to the extent of muscle paralysis providing there is complete motor denervation the extent of paralysis in both the thigh and the leg muscles would be expected to be equal and atrophy of femur and tibia would be similar Fig 4 demonstrates that there is a high correlation between bone ash loss in the femora and the tibiae in the paralyzed limbs but that atrophy in the tibia is greater than that in the femur and starts earlier, implying more complete denervation of the distal muscles

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From the Experimental Laboratory of the General Hospital of Bjorneborg (Pori) and from the Department of Pathology Section II University of Helsinki Helsingfors Finland (Head Professor Harald Teir M D)

EXPERIMENTAL EPIPHYSEAL TRANSPLANTATION

Part III *The Influence of Age*

By

HENRIK V A HEIKEL

INTRODUCTION AND PROBLEM

In two previous papers I have described radiological observations on the survival and growth of the autotransplanted proximal end of the fibula of the rabbit (*Heikel* 1960 (2)) and histological observations on the survival regeneration and growth of the transplants (*Heikel* 1960 (3)) I concluded that the peripheral parts of the transplanted epiphyseal cartilage survive and that from these parts a new epiphyseal cartilage regenerates but that the increased cell proliferation necessary for regeneration obviously exhausts the resources of the reserve zone with the result that there is early cessation of growth Besides it appeared that there was no difference between transplantations performed at different ages between 10 and 29 days

In clinical practice it is not always possible to carry out an epiphyseal transplantation at the corresponding age i e 1 to 2 years (*Heikel* 1960 (1)) It is therefore important to know to what extent the capacity for longitudinal growth is retained beyond this age and whether there is an age-limit after which the transplant loses this capacity either wholly or partly

The object of the present investigation has been to study whether the age at which a growing bone with epiphyseal cartilage is transplanted influences its capacity for longitudinal growth and if there is such an influence to study the way in which age plays a role and to determine the optimal age for the performance of epiphyseal transplantation

METHOD AND MATERIAL

The experiments were performed on 163 rabbits aged 10 to 70 days. The results were followed either histologically or radiographically and in a few cases in both ways (Table 1). The aforementioned investigations seemed to show that the site of the transplant was immaterial but that the important premise for its survival and growth was that it should fuse with the host bone. They further showed that in transplantation to the thigh the transplant often fused to the femur in a rather transverse position which made radiographic observations difficult. For this reason in the present work the proximal part of the right fibula was transplanted to the left leg where it was placed in front of the left fibula. In other respects the technique of transplantation of obtaining radiographs and of measuring growth were the same as in the earlier investigations. As no internal fixation was used the radiological observations in a number of experiments showed that the transplant did not fuse with the host bone. In a few weeks these grafts became atrophic and their epiphyseal line closed. Six of these transplants were found to have grown longitudinally before the closure of the epiphyseal line (from 1 to 3 and in a single experiment 7 mm) but in the majority of these there was no distinguishable growth. None of the experiments in which there was no radiological evidence of bone contact was included in the present series. Furthermore eight of the radiologically observed animals died or were killed at an early date and were therefore excluded.

TABLE 1

The Number of Animals of Different Ages and the Kind of Observation

Age of animal at transplantation of the fibula	Number of animals			
	Histologically observed	Radiologically observed	Radiologically and histologically observed	Total
1½-2 weeks	12	11		23
3 weeks	–	9	1	10
4 weeks	22	12	1	35
5 weeks		5		5
6 weeks	2	20		22
7 weeks	21	–	4	25
8 weeks		9	3	12
9 weeks	–	9		9
10 weeks	14	8	–	22
Total	71	83	9	163

HISTOLOGICAL OBSERVATIONS

80 rabbits were used for this part of the investigation. They were killed 2, 4, 6, 8, 10, 12, 14, 16 and 18 (and in some few experiments 20) days after the transplantation (Table 1). The transplant together with

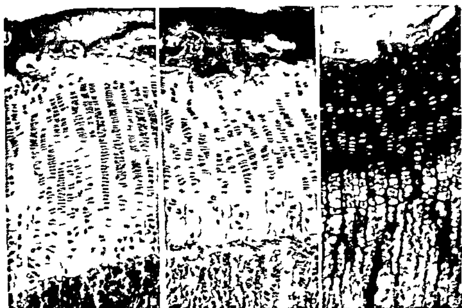


Fig 1

Normal epiphyseal cartilage of the fibula of the rabbit a at 6 weeks b at 10 weeks c at 12 weeks (a and b stained with haematoxylin eosin c with toluidine blue)

a part of the host bone was fixed in formalin decalcified sectioned and stained either with haematoxylin toluidine blue or PAS dye

For the sake of comparison the epiphyseal cartilage of the left fibula was simultaneously studied in a number of cases The following normal data should be mentioned the epiphyseal nucleus of the rabbit fibula becomes visible at the age of 10 to 17 days (*Hetkel* 1960 (1)) An epiphyseal plate is demonstrable from the age of about 4 weeks Initially however it is thin highly perforated and irregular From the age of about 6 weeks it is 0 2 mm thick and in parts compact while in its metaphyseal surface there are cavities occupied by capillaries The height of the epiphyseal cartilage at the age of 4 to 7 weeks is 0 6 mm and becomes gradually reduced so that at the age of 10 weeks it is 0 5 mm At the age of 150 to 22 days the epiphyseal line closes (*Hetkel* 1960 (1))

In my previous paper the term reserve zone was employed *Trueta* called the same cell layer "the germinative zone and since this denomination agrees better with my idea of the function of this zone (see below) I have adopted it in the present study Here as in my previous paper the border between the epiphyseal cartilage and the metaphyseal bone has been called the "metaphyseal border

After two and four days only degenerative changes were observed



Fig. 4
Experiment 360. Age group 1½ weeks, observation time 12 days. Beneath the thin epiphyseal plate there is only a thin germinative zone.

cartilage could not therefore be determined, but the distance from the nucleus to the metaphyseal border was about 2 mm (Fig. 3a). Nearest to this there was an area of necrotic cartilage which reached to the periphery of the transplant. From the metaphysis irregular connective tissue spurs had grown into the necrotic cartilage but actual calcification of the matrix had not occurred (Fig. 3b). On the epiphyseal side of this area there was a central cavity filled with erythrocytes, evidently haemorrhage from a capillary which had grown down from the epiphyseal nucleus. On either side of the capillary a new epiphyseal cartilage had regenerated, however, and contact between the nucleus and the site of the haemorrhage seemed to have been cut. The columns of new epiphyseal cartilage were sparse and irregular and their hypertrophic zone very high.

After twelve days the epiphyseal nucleus showed a suggestion of an epiphyseal plate. The entire growth cartilage had regenerated but beneath the epiphyseal plate the germinative zone was very low (Fig. 4) and the columns of cartilage cells were irregular and in places sparse. Along the entire metaphyseal border calcification of the intercellular substance of the cartilage had taken place. The primary bone trabeculae in the metaphysis were lined with osteoblast-like cells. About 2 mm from the metaphyseal border there was a transverse streak of uncalcified remnants of necrotic cartilage which showed the extent of the longitudinal growth. The transplant had fused with the host bone



Fig 5
Experiment 358 Age group 1 ½ weeks observation time 16 days The regenerated epiphyseal cartilage looks normal but the central part of the germinative zone is thin Note the fusion with the host bone (bottom right)

After fourteen and sixteen days the epiphyseal cartilage looked almost normal except that the central part of the germinative zone was very thin Between the nucleus and "the ossification groove there were large areas of undifferentiated cartilage rich in cells (Fig 5) At the metaphyseal border ossification seemed almost normal and the graft had fused

Transplantation at the Age of 4 Weeks

(At the time of the transplantation the transplants had an ossification nucleus in the epiphysis but the nucleus had no epiphyseal plate Thus there was a considerable amount of undifferentiated cartilage beside the nucleus)

After six days the height of the epiphyseal cartilage was 1 to 1 1 mm in the centre Only a border zone of the cartilage 0 3 to 0 7 mm wide appeared vital Streaks of fibroblasts and capillaries growing into the metaphysis reached the metaphyseal border in the periphery but calcification of the matrix had not occurred

After eight days epiphyseal cartilage had generated in the periphery



Fig. 6

Experiment 276. Age group 4 weeks, observation time 8 days. (Stained with toluidine blue.) a. The mushroom shaped necrotic cartilage in the centre had a rupture beneath the epiphyseal plate. On both sides there is regenerating epiphyseal cartilage compressing the necrotic part. To the right there is enchondral ossification. Opposite the necrotic cartilage the metaphysis contains no living cells. b. Rupture with erythrocytes and streaks of fibrocytes and capillaries growing from the nucleus into the necrotic cartilage.

areas, and its columns contained a very large number of hypertrophic cells. At the metaphyseal border calcification of the cartilage matrix had set in. In the centre, the necrotic area, evidently as a result of expansion of the regenerating cartilage, had taken on a mushroomlike shape with still longer columns. At the metaphyseal border of the "mushroom" no calcification was visible. Thus the necrotic cartilage was subject to a gradual overgrowth by the peripheral parts of the metaphysis (Fig. 6a). Within the necrotic cartilage at the border *between the germinative and proliferative zones there was a rupture with* haemorrhage from a capillary which had grown down from the epiphyseal nucleus (Fig. 6b).

After ten and twelve days a distinct epiphyseal plate was still missing. From the nucleus capillaries had grown down into the necrotic cartilage. In the border areas of the epiphyseal cartilage regeneration occurred which seemed to have expanded towards the centre, compressing the necrotic area. In the metaphysis capillaries and streaks of fibroblasts had reached the whole metaphyseal border and in the peripheral areas



Fig 7

Experiment 29? Age group 4 weeks observation time 14 days The regenerated peripheral parts of the epiphyseal cartilage seem to diverge from the areas of undifferentiated cartilage at the "corners" of the nucleus Beneath the central part of the epiphyseal plate there is only necrotic germinative zone A bony bridge from the nucleus to the metaphysis and in the metaphysis remnants of the necrotic cartilage are seen (bottom)

calcification of the matrix of the regenerated epiphyseal cartilage had taken place

After fourteen and sixteen days the nucleus had developed an epiphyseal plate which reached close to the surface of the transplant Beneath the centre of the plate remnants of the germinative zone of the necrotic cartilage were visible In the periphery there were large areas of regenerated epiphyseal cartilage which in the section resembled two berets because the cartilaginous columns diverged from points beneath the "corner of the epiphyseal nucleus where there were still comparatively large areas of undifferentiated cartilage At the metaphyseal border of the regenerated epiphyseal cartilage ossification and longitudinal growth had taken place In the centre the columnar zone of the necrotic cartilage had been torn loose from the germinative zone and overgrown by the peripheral growth so that the remnants of the necrotic cartilage were lying below in the metaphysis about 2 mm from the metaphyseal border A partly ossified connective tissue bridge had developed here between the nucleus and metaphysis (Fig 7) In



Fig. 8.
Experiment 31?. Age group 4 weeks. Observation time 10 days. The necrotic cartilage is not definitely peeled off but from its metaphyseal side it is broken up by ingrowing connective tissue and capillaries. Beneath the "corners" of the nucleus there is undifferentiated cartilage and in the central parts there are round expanding cartilage islets. The regeneration of the epiphyseal cartilage is nearly complete.

other experiments the epiphyseal plate had not yet developed and between the nucleus and the ossification groove as also centrally in the epiphyseal cartilage expanding islets of undifferentiated cartilage could be observed (Fig. 8). The necrotic area had not been definitely peeled off and ossification of the *regenerated epiphyseal cartilage* had occurred within narrow border areas only.

After eighteen to twenty one days the epiphyseal cartilage had regenerated with the exception of the *germinative zone* which was almost entirely missing in the centre. Here, instead, there was often a bony bridge between the nucleus and the metaphysis. In the metaphysis at a distance of about 3 mm from the metaphyseal border remnants of necrotic cartilage were seen.

Transplantation at the Age of 7 Weeks

(At the time of the transplantation the epiphyseal nucleus had an epiphyseal plate reaching close to the surface of the transplant.)

After six days the epiphyseal cartilage was 0.6 mm high. Only within a small peripheral area on the metaphyseal side of the ossification



Fig 9

Experiment 349 Age group 7 weeks observation time 10 days Streaks of fibrocytes grow from the surroundings in between the necrotic cartilage (bottom left) and the regenerated cartilage (top right) and from the metaphysis between the columns of the necrotic cartilage

groove did the cartilage look vital and there was a suggestion of column formation

After eight days the regenerated areas were somewhat larger and peripherally the cartilage matrix has ossified to a depth of about 0 2 mm In other places connective tissue streaks had grown from the surroundings of the transplant in between the regenerated and the necrotic cartilage which here reached the surface of the transplant In the epiphyseal nucleus capillaries were seen in the metaphysis mainly streaks of fibroblasts but also a few capillaries which had grown for ward to the metaphyseal border

After ten days the epiphyseal cartilage was 0 5 to 0 7 mm high It looked entirely devitalized and there were patches of detritus In the metaphysis fibroblasts and capillaries had grown to the metaphyseal border except in the centre where there was a small area with detritus From the surroundings connective tissue had grown in between the regenerating and the necrotic cartilage (Fig 9)

After twelve and fourteen days the epiphyseal cartilage was necrotic with the exception of small regenerating border areas where ossifica tion had occurred to a depth of 0 2 to 0 4 mm over a maximum width -



Fig. 10

Experiments 36f. Age group 7 weeks, observation time 16 days. a. The epiphyseal cartilage is regenerated and looks fairly normal (cf. Fig. 1b); remnants of the necrotic cartilage are seen in the metaphysis and there is contact with the host bone (bottom). b. Most of the germinative zone is necrotic.

of 0.7 mm, some overgrowth over the necrotic cartilage having taken place.

After 16 and 28 days the peripheral growth in length had in some experiments resulted in a mushroom shape of the necrotic cartilage and partial overgrowth by the metaphysis. From the latter irregular *spurs of connective tissue and capillaries from the sides and from the* metaphyseal border had grown into the necrotic cartilage. In other experiments the epiphyseal cartilage had regenerated except that in the centre of the germinative zone almost all cells looked devitalized (Fig. 10 a and b). The remainder of the necrotic cartilage constituted a transverse streak in the metaphysis about 1½ mm from the metaphyseal border. The transplant had fused to the host bone.



Fig 11

Experiment 289 Age group 10 weeks observation time 14 days (stained with toluidine blue compare with Fig 1 c) The regenerated cartilage (dark stained right) is separated from the metaphysis by the (light stained) narrow streak of necrotic cartilage and ossification has not started

Transplantation at the Age of 10 Weeks

(At the time of the transplantation the plate of the epiphyseal nucleus reached close to the periphery of the transplant)

After six days the epiphyseal cartilage was 0 5 mm high and looked devitalized except for small triangular border areas There was an abundance of detritus in the metaphysis and ingrowing capillaries and fibroblasts were no closer to the metaphyseal border than 2 mm

After eight days the small areas of regenerated cartilage were still separated from the metaphysis by the necrotic cartilage which reached to the surface of the transplant In the border areas of the metaphysis capillaries and streaks of fibroblasts reached as far as the metaphyseal border

After fourteen days the regenerated cartilage was still separated from the metaphysis (Fig 11) In the necrotic cartilage there were patches of detritus From the epiphyseal nucleus capillaries had grown down into the cartilage From the surroundings connective tissue had grown in along the metaphyseal surface of the epiphyseal plate There was an abundance of capillaries in the metaphysis and a lining of osteoblast like cells on the primary bony trabeculae but ossification of narrow border areas of the epiphyseal line was visible in a few preparations only

After twenty one days the epiphyseal line had fused almost com

pletely in some preparations, while in others an epiphyseal cartilage 0.05 to 0.15 mm high and without a germinative zone was visible. The metaphysis had fused with the host bone. 2 mm from the metaphyseal border a transverse band of necrotic cartilage was seen.

RADIOLOGICAL OBSERVATIONS

The number of experiments in which bone contact was detected was 72. 63 animals were observed to an age of 100–170 days, and 23 of these to over 170 days, an age at which the growth of the fibula of the rabbit is as a rule almost complete (*Heikel* 1960 (1)). In about 3/4 of the experiments the position of the transplant allowed radiographic measurement of the growth (Table 2). It should be noted that in the three youngest groups the percentage of cases in which bone fusion occurred was almost 100, but in the older groups only 50–75. This may have depended on a greater ability of the younger transplants to survive, but may have resulted from the greater technical difficulties of transplantation in the older animals, too.

TABLE 2

The Number of Experiments in which the Transplant Showed Radiological Evidence of Contact with Host Bone

Age of animal at transplantation of the fibula	Total	Number of animals: Observed to an age of at least 100 days	Number of animals: Measurement of growth possible
1½–2 weeks	11	8	8
3 weeks	9	8	8
4 weeks	12	8	8
5 weeks	3	2	1
6 weeks	17	17	15
7 weeks	3	3	2
8 weeks	6	6	3
9 weeks	6	6	2
10 weeks	5	5	0

The mean growth of the transplants and the extreme variations are shown in Table 3. After transplantation at an age of 1½–2 weeks the fibula retained in mean 50 and in the most successful experiment as much as 80 per cent of its capacity for longitudinal growth. In the 3 week group the corresponding figures had fallen to 36 and 65, in the

6 week group to 21 and 41 and in the 8 week group to 15 and 27 per cent respectively

TABLE 3

The Longitudinal Growth of the Transplanted Fibula in Relation to the Left (Control) Fibula

Age of animal at transplantation of the fibula	Mean age of the animals at the end of the observation time	Longitudinal growth of the transplanted fibula relative to the growth of the left fibula (%)	
		Mean	Variations
1½–2 weeks	143 days	50	5 – 81
3 weeks	164 days	36	0 – 65
4 weeks	136 days	18	0 – 48
6 weeks	139 days	24	0 – 41
8 weeks	174 days	15	0 – 27
9 weeks	179 days	11	0 – 13

DISCUSSION

A comparison of the four age groups in the histological series shows that re nutrition of the transplant required two days less in the two youngest groups This is probably due only to the fact that in these the volume of the transplant was less and the capillaries had to grow a shorter distance but anyhow it resulted in a promotion of the regeneration of the surviving epiphyseal cartilage In all experiments the latter comprised a border area of more or less equal width (ca 0 6 mm) which indicates that survival was made possible through nutrition by diffusion from the surroundings In experimental lesions of epiphyseal vessels *Trueta* noticed that a border area of the epiphyseal cartilage was supplied by vascular anastomoses around the plate but he did not mention its width It is possible that it is this area that survives although at transplantation the anastomoses are cut

Regeneration of the epiphyseal cartilage was quickest and most complete in the youngest age groups This might again be due to the comparatively small volume of the transplants in these groups One cannot however disregard the fact that as long as there is no epiphyseal nucleus or the nucleus is small and its epiphyseal plate does not reach close to the surface of the transplant the epiphyses contains a large amount of undifferentiated cartilage which might be assumed to be mobilized to replace the necrotic germinative zone As soon as the epiphyseal plate has developed fully (at the age of about 6 weeks) access to undifferentiated cartilage is highly limited

Trueta mentions that the origin of the germinative zone is still unexplained. It has, for example, been assumed that cell production takes place at the ossification groove. In none of my preparations has the histological picture suggested this to be the site at which the cartilage cells are produced; on the contrary, there has been some evidence of cell production within the undifferentiated cartilage between the epiphyseal nucleus and the ossification groove (Figs. 6, 7 and 8).

The regenerated epiphyseal cartilage extends towards the centre of the transplant partly through a fan-like divergence of the columns towards the centre of the transplant and possibly through the formation of new columns medially of the first columns. Thus the columnar zone of the necrotic cartilage is compressed from the sides and in the direction of the metaphysis (*Heikel* 1960 (3) and *Trueta* 1960 (6)). Since *the columns grow obliquely towards the centre, the germinative zone* lags behind and, in the centre of the transplant, is low or entirely missing. Through pressure from the sides concentrated towards the columnar zone of the necrotic cartilage, the columnar zone is torn loose from the germinative zone, which remains beneath the centre of the epiphyseal plate. This was most pronounced in the oldest age groups and is the reason why growth soon ceases for want of new formation of cartilage cells. *Trueta* has also described a rupture of the ischaemic cartilage, usually at the metaphyseal end, in experimental interruption of the nutrition of the epiphysis, but he did not mention whether the rupture always took place in the same layer.

The difference in the speed at which nutrition was reestablished on the metaphyseal side does not seem to have been the conclusive factor accounting for the difference between the groups. Even though the calcification of the matrix of the epiphyseal cartilage cannot take place before the capillaries have reached the metaphyseal border, it is evident that only cartilage cells which have undergone the normal degenerative process can be subject to this ossification process. In the older groups the necrotic cartilage had long acted as a barrier between the regenerating cartilage areas and the metaphysis. According to *Trueta*, such a barrier, if persisting for a minimum of 10 days, may become permanent. This was probably the case in experiment no. 289 (Fig. 11). If, however, the barrier is broken by contact between the surviving cartilage and the metaphyseal capillaries either from the beginning or through the growth of the former, ossification and growth in length here occur in the usual way. During the time that passes before ossification sets in, the columns of the epiphyseal plate have grown by about 50 per cent of their normal

length through an increase in the number of hypertrophic cells This a fact also observed by *Trueta* is the reason why the height of the epiphyseal cartilage increases during the first few days after transplantation When contact has been established with the epiphyseal vessels these cells evidently rapidly undergo their normal degenerative process and thereafter ossification proceeds rapidly until the regenerated areas of the epiphyseal cartilage have reached a normal height This explains the short period of rapid growth which the growth curves of the transplants exhibit (*Heikel* 1960 (1) Fig 10) The necrotic cartilage is thus overgrown and its peeling off is facilitated If the latter does not occur rapidly enough and if the expansion of the regenerating cartilage towards the centre of the transplant is delayed the capillaries grow down from the epiphyseal nucleus followed by connective tissue This may also happen from the metaphysis along the border between the regenerating and necrotic cartilage When contact between the epiphyseal nucleus and the metaphysis is established a bony bridge is formed through ossification and growth ceases

The number of experiments observed radiologically is comparatively small and the results vary greatly From Table 3 one gains the impression however that the changes of a transplant preserving 50 per cent or more of its capacity for growth in length—under given experimental conditions—are good if transplantation is carried out at the age of 1½ to 2 weeks small if transplantation takes place at the age of 3 and 4 weeks and minimal at the age of 7 and 10 weeks

CONCLUSIONS

The histological observations which are in good agreement with *Truela's* observations on selective interruption of the nutrition of the epiphyseal cartilage partly on the epiphyseal and partly on the metaphyseal side seem to explain why the transplant stands a good chance of preserving a significant amount of its capacity for growth in length only if transplantation is carried out on a young animal They cannot explain however why the result seems to depend on fusion of the transplant with the host bone Seemingly all regenerative processes which determine the degree of retained capacity for longitudinal growth have occurred before or simultaneously with the occurrence of bony fusion Here biological factors which cannot be identified on the basis of the present experiments may possibly play a role

What are the practical consequences of the present observations?

If transplantation is carried out at an early age the transplant would *under normal conditions have a long growth period and a comparatively small percentual growth inhibition would result in considerable limitation of the final length.* If on the other hand transplantation is not carried out until significant growth in length has already taken place a growth inhibition which reckoned as a percentage is smaller *need not result in a great final shortening.* This can be calculated theoretically on the basis of the figures in Table 3 and the normal growth curve for the rabbit fibula (*Heikel* 1960 (1)) provided that at the time of the transplantation each transplanted fibula is of normal length and has a normal capacity for longitudinal growth. Table 4 shows that *if this theoretical calculation is correct there should be no* significant difference between the final lengths of the transplants in the different age groups.

TABLE 4

The Theoretically Calculated Final Length of the Transplanted Fibula at the End of the Growth Period

Age of animal at transplantation of the fibula	Normal length of fibula at age of transplantation (mm)	Normal longitudinal growth during the remaining growth period (mm)	Observed mean longitudinal growth percentage	Theoretically calculated	
				Mean longitudinal growth of the transplant (mm)	Final length of the transplant (mm)
1½–2 weeks	13	37	50	18.5	31.5
3 weeks	16	34	36	12.0	28.0
4 weeks	19	31	18	5.5	24.5
6 weeks	23	27	24	6.5	29.5
8 weeks	28	22	15	3.5	31.5
9 weeks	30	20	11	2.0	32.0

Under certain experimental conditions in the rabbit the most favourable time for transplantation if the chief stress is laid upon the growth in length of the transplant is the age of 1½ to 2 weeks but if the chief stress is laid upon the final length of the transplant the age of the experimental animal is of no conclusive significance.

To what extent these observations are applicable to clinical conditions and to transplants of larger volume cannot be determined on the basis of the present investigation.

SUMMARY

The proximal part of the right fibula was transplanted to the left leg of 163 rabbits aged 1½–2, 4, 7 and 10 weeks respectively. The survival

and longitudinal growth of the transplant was observed radiographically and histologically

The renutrition of the transplant required two days less in the two youngest groups which promoted the regeneration of the surviving parts of the epiphyseal cartilage The regeneration was most complete in the youngest groups This was supposed partly to be a consequence of the fact that as long as the epiphyseal nucleus is small there is a large amount of undifferentiated cartilage in the epiphysis which might be assumed to be mobilized to replace the non surviving part of the germinative zone If this part is not replaced—as was the case in the older groups—the longitudinal growth of the transplant soon ceases for want of new formation of cartilage cells

There seemed to be good changes of a transplant preserving 50 per cent or more of its capacity for longitudinal growth only if the transplantation was carried out at the age of 10–14 days and minimal chances at the age of 7 and 10 weeks

RÉSUMÉ

La partie proximale du cotyle droit a été transplantée à la jambe gauche chez 163 lapins âgés de 1½–2 4 7 et 10 semaines respectivement La survie et la croissance longitudinale de la transplantation on été observées radiographiquement et histologiquement

La renutrition de la transplantation demande deux jours de moins dans les deux groupes d âge les plus jeunes chez lesquels s opère la régénération de la partie survivante du cartilage épiphysaire La régénération a eté la plus complete dans les groupes les plus jeunes Cela a été supposé être partiellement la conséquence du fait qu aussi long temps que le noyau épiphysaire est petit il y a une grande quantité de cartilage non différencié dans l épiphyse qui peut être mobilisé pour remplacer la partie non survivante de la zone germinative Si cette partie n est pas remplacée – comme ce fut le cas pour le groupe plus âgé la croissance longitudinale de la transplantation cesse rapidement par suite du besoin de nouvelle formation de cellules cartilagineuses

Il semble qu il y ait de bonnes chances pour une transplantation qui a conservé 50 pour cent ou plus de sa capacité de croissance longitudinale pourvu que la transplantation soit operée à l âge de 10 à 14 jours et des chances minimes à l âge de 7 et 10 semaines

ZUSAMMENFASSUNG

Der proximale Teil der rechten Fibula wurde auf das linke Bein von 163 Kaninchen, die 1½–2, 4, 7 und 10 Wochen alt waren, verpflanzt. Das Überleben und Längenwachstum des Transplantates wurde röntgenologisch und histologisch beobachtet.

Die Wiederernährung des Transplantates erforderte in den beiden jüngsten Gruppen zwei Tage weniger, was die Regeneration der überlebenden Teile des Epiphysenknorpels begünstigte. Die Regeneration war am vollkommensten in den jüngsten Gruppen. Augenscheinlich war dies teilweise eine Folge der Tatsache, dass in einem Stadium, in dem der Epiphysenkern klein ist, eine grosse Menge von undifferenziertem Knorpel vorhanden ist, von dem man annehmen kann, dass er mobilisiert wird, um den nichtüberlebenden Teil der Wachstumszone zu erstatten. Wenn dieser Teil nicht erstattet wird – wie es der Fall in der älteren Gruppe war – dann hört das Längenwachstum des Transplantates wegen mangelvoller Neubildung von Knorpelzellen bald auf.

Gute Möglichkeiten, dass das Transplantat 50 Prozent oder mehr seiner Fähigkeit zum Längenwachstum bewahrte, schienen nur vorhanden zu sein, wenn die Verpflanzung im Alter von 10–14 Tagen vorgenommen wurde, während die Aussichten im Alter von 7 und 10 Wochen sehr gering waren.

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EXPERIMENTAL KNEE-JOINT FRACTURES

A Preliminary Report

By

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INTRODUCTION

There have been many previous studies relative to experimental fractures and dislocations of the knee joint (1–8) With the exception of recent work by Kennedy the full results of which have yet to be published there has been relatively little experimental work that has attempted to determine whether fractures can be produced that correspond to known compressive forces The present study is designed to accomplish this purpose

MATERIAL AND METHOD

The study was performed on knee joints obtained at autopsy from 32 subjects who were free of disease known to affect the skeletal system They were tested fresh or after freezing at −20° C for less than one month Frozen specimens were tested immediately after thawing The specimens consisted of the knee joint and about 15 cm of the extremity above and below the joint from which the skin subcutaneous fat and muscle had been removed The subjects ranged from 38–84 years with a predominance in the 60–80 year group There were 13 males and 19 females

In order that the specimens could be held in position during the experiments the diaphyses were embedded in metal boxes in Plastic Padding A The desired amount of knee joint flexion could be set and controlled at any desired amount during embedding by a specially designed apparatus (Fig 1) The specimens were then transferred to a hydraulically powered machine where they were loaded progressively from 0 at a rate of 100 kg/min (Fig 2) Load and distance between the loading and supporting heads were recorded by a kymograph (Fig 3) When the curve that was being recorded showed signs of flattening or reversal the experiment was discontinued Often the sound of fracture could be heard at this point The specimen was then removed and dissected for determination of the damage A-P and lateral roentgen grams were taken before during and after the experiment After completion of dissection the specimen was sliced with a band saw in the sagittal or frontal plane depending on the fracture Each slice was inspected and radiographed

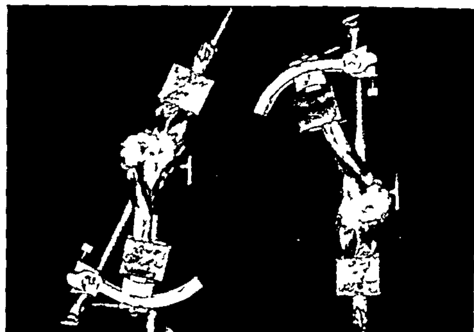


Fig. 1

Apparatus for embedding the specimen in Plastic Padding. The box at the end of femur can be moved along the curved metal fork until the required angle of the knee joint is obtained. The whole preparation can be rotated through 180° to enable the other box to be filled with Plastic Padding without disturbing the adjustment in the joint.

RESULTS

The injuries that were produced fell into three categories—Bony, Ligamentous or None. There was no case in which bone and soft tissue injury were combined. Four specimens had no definite sign of injury. In three there were injuries of the posterior cruciate ligament and in one specimen the lateral meniscus was ruptured. Fracture of the femoral condyle was seen in two cases, and in one of these the fibular head contained a small fracture. The tibia was fractured in the remaining twenty two cases.

The tibial fractures were divided into four groups. The first (3 specimens) demonstrated compression of the spongiosa approximately one cm below the articular surface. These fractures were not seen clearly on the radiographs but they were visible when the specimens were being sawn. They were termed subcortical compressions and they occurred at flexions greater than 20° and at a smaller load than was

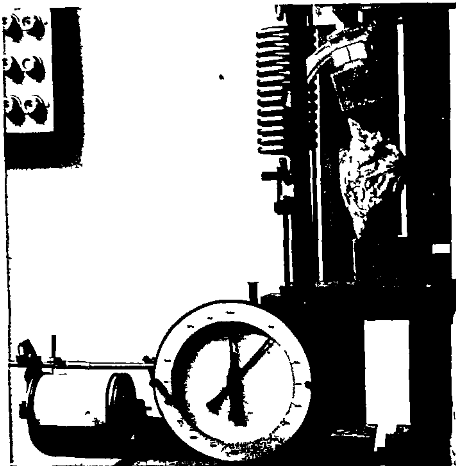


Fig 2
The specimen mounted in the testing machine

required to produce the other types of fracture (Table 1) The second group (6 specimens) demonstrated depression of either one or both tibial condyles (Fig 4) The third group (12 specimens) included fractures of a more severe nature often sagittal in direction and originating at or near the intercondylar area and running toward the medial or lateral aspect of the tibia These were referred to as split fractures (Fig 5) The fourth group consisted of four severely comminuted fractures (not included in Table 1)

It can be seen in Table 1 that pure split fractures were usually produced with 20 of flexion or less Greater angles than this usually pro-

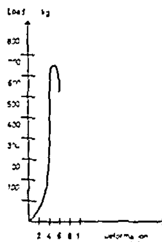


Fig. 3
A curve obtained in a loading experiment on the knee joint. The ascending part occupies about seven minutes, whereas the descending limb, which represents loading of the already fractured joint, covers a few seconds.

TABLE 1
Various Types of Fractures of the Tibial Condyles Produced with a Varied Load and the Knee Joint Flexed

Age	Sex	Flexion (°)	Load producing compression of subcorticalis (kg)	Load producing depression of condyle (kg)	Load producing split fracture (kg)
44	♂	0			780
63	♂	0			1010
74	♂	0			1030
69	♂	5			770
79	♀	5			1010
63	♀	5			440
60	♂	15			980
74	♂	15		730	
81	♂	20			490
84	♂	20		735	735
70	♂	25		750	750
79	♀	25	375		
50	♀	30		500	510
60	♂	30		500	
38	♂	30		510	
82	♀	30	280		
58	♂	35			490
		55	360		



Fig 4
Lateral view Depressed lateral condyle of the tibia Woman of 50 Flexion 30 Maximum load 510 kg

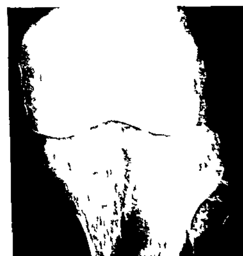


Fig 5
Anteroposterior view Split fracture Man of 44 Knee joint in extension Maximum load 780 kg

duced depression of the tibial condyle which was accompanied by split *fracture in 3 cases The cases with subcortical compression and soft* tissue injuries were produced with flexion angles greater than 20 No further relation between degree of flexion and type of injury could be determined

Fractures were produced with loads ranging from 280–1070 kg There was a tendency for fracture load to be greater for an extended knee than for a flexed knee (Table 2) but no statistically significant



Fig 6 a



Fig 6 b



Fig 6 c



Fig 6 d

Fig 6 a Compression experiments at 30° flexion Woman of 50 Load 250 kg *No fracture*

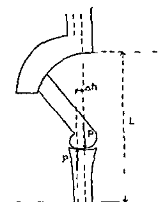
Fig 6 b Load 480 The lateral tibial condyle of the tibia is depressed

Fig 6 c Load 510 kg The depression is increased A split fracture has occurred and the medial fragment of the tibia has been dislocated

Fig 6 d Load decreased to zero The fragment has been reduced spontaneously

TABLE 2
Mean Load for Various Types of Fractures Relation between Angle of Flexion and Load at which Various Types of Fractures Occur

0 — 20	800 kg
> 20 (subcortical compressions excepted)	550 kg
subcortical compressions	320 kg



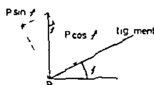


Fig 7

An attempt was made to analyse the moments If the lines of action of the upper and lower compressive force P do not coincide application of the force may result in a bending moment about the knee joint With a distance Δ h between the lines of action the bending moment is $P \Delta h$/? If $\Delta h = 0$ there will no bending moment until the critical point of buckling of P is reached From this point P_k any further compressive energy is converted to bending energy —P_k is given by the expression $\frac{EI}{P_k} L^2 = 4 \pi^2$ where E is the modulus of elasticity I is the moment of inertia L the distance between supporting heads If this bending moment acts about the knee joint it will give rise to bending and *compressive stresses the magnitude of which* is $\frac{M}{I}$ Z where M is the bending moment and Z is distance from the centre of bending (positive or negative) However these bending and compressive stresses act almost perpendicularly to the ligament and are primarily taken up in normal flexion of the knee joint Any component in the direction of the ligament cannot be determined accurately On the other hand the ligament forms an angle φ with the (horizontal) articular surface If it is assumed that I is taken up at the attachment of the ligament the component P cos φ should constitute the compressive force on the bone (and any rotation of the ligament) while the component P sin φ (that is the force T) stretches the ligament For a rupturing force p of 700 kg the stresses on the ligament for some practical values of flexion will be as follows

φ	0	5	10	20	30
sin φ	*0*	*0 087*	*0 174*	*0 342*	*0 500*
T(kg)	0	60	120	240	350

differences could be determined between load and type of fracture or load and amount of flexion combined in producing fracture

Soft tissue injury was produced in the 300–700 kg range There are several possible explanations for soft tissue injury in this type of experiment one of which is indicated below In four cases no injury was seen although the curve appeared to flatten in the usual range This can be the result of premature cessation of the test or submicroscopic damage

From a series of anteroposterior radiographs taken in an experiment, in which both depression and split fracture was obtained it was evident that depression occurred first (Fig 6) The last two radiographs of the series showed that when the load was decreased to 0 the dislocation of the fragments was reduced

The difference in load between flexion and extension causing lesions may possibly be ascribed to (i) the decrease in the area of contact as the angle of flexion is increased resulting in an increase in the load per unit of area because of the shape of the femoral condyles (ii) a change in the action of the intra articular forces from the cruciate ligaments and (iii) differences in the moments at the critical point of buckling for different angles of flexion (Fig 7)

SUMMARY

A method producing intra articular injuries in autopsy knee joint specimens is described Only vertical loading with differing flexion angles of the knee has so far been studied Most of the injuries were fractures and occurred in the tibial condyles These were of three types subcortical compressions condylar depressions and split fractures

The type of fracture of the tibial condyle appeared to be dependent on the angle of flexion Angles exceeding 20 produced first condylar depression and then a split fracture Extension resulted in split fractures The load required to produce a fracture tended to be greater for the extended than the flexed joint

RESUME

Il est décrit une méthode pour produire des lésions intra articulaires a l autopsie de specimens d articulations du genou Jusqu ici seule une charge verticale avec différents angles de flexion du genou a été etudiée La plupart des lésions étaient des fractures du condyle tibial Celles ci

étaient de trois types compressions sous corticales dépressions condylaires et ruptures osseuses

Le type de fracture du condyle tibial est dépendant de l angle de flexion Les angles dépassant 20 produisent d abord une dépression condylaire puis rupture L extension provoque une rupture La charge requise pour produire une fracture de l os est plus forte pour l articulation en position d extension que pour celle en position de flexion

ZUSAMMENFASSUNG

Eine Methode die intraartikulare Schaden an Autopsiepraparaten des Kniegelenkes hervorruft wird beschrieben Nur vertikale Belastung mit verschiedenem Beugewinkel des Kniegelenkes ist vorlaufig studiert worden Die Mehrzahl der Schäden waren Bruche die in den Tibia kondylen entstanden Es traten drei verschiedene Typen auf Subkortikale Kompressionen kondyläre Depressionen und Spaltungsbrüche

Die Bruchtype des Tibiakondyles schien vom Beugungswinkel abhängig zu sein Winkel uber 20 erzeugten erst kondylare Depression und dann Spaltungsbrüche Extension ergab Spaltungsbruche Die Belastung welche man zur Hervorrufung eines Bruches verwenden musste war im allgemeinen grosser bei gestrecktem als bei gebeugtem Gelenk

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differences could be determined between load and type of fracture or load and amount of flexion combined in producing fracture.

Soft tissue injury was produced in the 300–700 kg range. There are several possible explanations for soft tissue injury in this type of experiment, one of which is indicated below. In four cases no injury was seen, although the curve appeared to flatten in the usual range. This can be the result of premature cessation of the test or submicroscopic damage.

From a series of anteroposterior radiographs taken in an experiment in which both depression and split fracture was obtained it was evident that depression occurred first (Fig. 6). The last two radiographs of the series showed that when the load was decreased to 0 the dislocation of the fragments was reduced.

The difference in load between flexion and extension causing lesions may possibly be ascribed to (i) the decrease in the area of contact as the angle of flexion is increased resulting in an increase in the load per unit of area because of the shape of the femoral condyles, (ii) a change in the action of the intra-articular forces from the cruciate ligaments and (iii) differences in the moments at the critical point of buckling for different angles of flexion (Fig. 7).

SUMMARY

A method producing intra-articular injuries in autopsy knee joint specimens is described. Only vertical loading with differing flexion angles of the knee has so far been studied. Most of the injuries were fractures and occurred in the tibial condyles. These were of three types: subcortical compressions, condylar depressions and split fractures.

The type of fracture of the tibial condyle appeared to be dependent on the angle of flexion. Angles exceeding 20° produced first condylar depression and then a split fracture. Extension resulted in split fractures. The load required to produce a fracture tended to be greater for the extended than the flexed joint.

RÉSUMÉ

Il est décrit une méthode pour produire des lésions intra-articulaires à l'autopsie de spécimens d'articulations du genou. Jusqu'ici seule une charge verticale avec différents angles de flexion du genou a été étudiée. La plupart des lésions étaient des fractures du condyle tibial. Celles ci

for inward and outward rotation *DePalma* (3) states that the division of the tibial collateral ligament does not result in any rotation in the extended position but that at 150 the outward rotation is increased from the normal 6–8 to 30 The inward rotation is unaffected *Brantigan et al* (2) report that there was no increase in the rotation when the tibial collateral ligament was divided whether in extension or in the 90 or 30 positions When both collateral and both cruciate ligaments were divided the range of rotation was increased in all positions in extension it was on an average 14 and in the 90 position 31 No distinction was made between inward and outward rotation

NOMENCLATURE

In connection with rotation in the knee joint and especially the screw home movement the term "inward rotation is used sometimes to denote rotation of the femur inwards in relation to the tibia and sometimes to denote rotation of the tibia inwards in relation to the femur In the present study inward and outward rotation refer to the movement of the tibia in relation to the femur Since as will be evident from results reported below a considerable rotation takes place in both extension and flexion positions it is necessary in any discussion of outward and inward rotation in the knee-joint to define the initial position This would seem however to present a major difficulty in extension and especially in flexion positions where an active rotation is possible For this reason we preferred to record the *total rotation* in the knee joint—that is the range of rotation between the two extreme positions As regards the various positions of the knee joint *extension* refers to the position of the joint where resistance to further extension is encountered whether in the 180 or 190 position The *flexion* positions are expressed in terms of the angle between the thigh and the lower leg

MATERIAL

The study was performed on 16 fresh knee joints from cadavera The age and sex distributions were as follows

	≤ 40	41 60	> 60 years
Men	–	4	3
Women	1	2	6



Fig 1

Apparatus for measuring the lateral mobility of and rotation in the knee joint

METHODS

To be able to measure the rotation between the femur and tibia in different flexion positions of the knee joint an apparatus was designed one part of which is fixed to the femur and the other to the tibia (Fig 1) The rotation in any desired position of flexion could be read off on a graduated scale So as to reduce the number of values the rotation was determined in 4 positions of the knee joint—namely in extension and at flexion angles of 1C0 120 and 90

The rotation was recorded in these positions for intact knees and then with the superficial portion of the tibial collateral ligament its deeper portion and the anterior and posterior cruciate ligaments divided in turn The outward and inward rotations were recorded separately but because of the difficulty of defining accurately an initial or neutral position the total rotation was generally used The neutral position was taken as the position which the knee assumed spontaneously without application of any external force in the outward or inward directions of rotation However this position is particularly unstable after division of the ligaments

The magnitude of the rotational movement especially when the ligaments had

been divided was largely dependent on the force applied in rotating the lower leg In the tests one investigator fixed the femoral part of the instrument and hence the femur while the other investigator without looking at the scale manipulated the lower leg with a moderate force which as far as possible was made the same for the different tests

This method was tried out on 5 knee joints and the actual experiments were then performed on 11 consecutive joints By the standardized procedure with identical tests in all cases and division of the ligaments in the same order it was possible to calculate whether the differences in rotation obtained were statistically significant The usual methods of statistics were used and the values of P were calculated by means of Student s t test

RESULTS

The tests on 11 knee joints in 4 flexion positions and in 5 different types of lesion of the ligaments gave 440 observations of angles of inward and outward rotation or 220 of total rotation Since such a large number of values would be difficult to survey and would be unpalatable in tabular form the results are presented as means

It is seen from Table 2 that there was also considerable rotation of the intact knee joints in extension Moreover of the 4 positions the rotation of the intact knee was greatest for 120 The difference in rotation between the 120 and the other positions was significant ($P < 0.01$) A significantly ( ) greater rotation in the 120° position was also found after division of the various ligaments

TABLE 2
Mean Total Rotation in the Knee-Joint in Different Positions

	Extension	160	120	90
Rotation in intact knee	11	25	29	26
Range	2 18	17–35	25–35	19–33
After division of				
Tibial collat lig				
superficial portion	15	34	41	32
+ deep portion	17	47	55	45
+ Anterior cruciate lig	21	57	70	64
+ Posterior cruciate lig	19	55	73	67

Division of the ligaments in turn as described above resulted in a progressive increase in the range of rotation Except for the posterior cruciate ligament this was significant ( ) for each new step in the positions 160 120 and 90 In exten ion the rotation increased as each

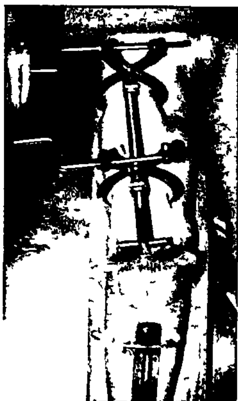


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The rotation was recorded in these positions for intact knees and then with the superficial portion of the tibial collateral ligament its deeper portion and the anterior and posterior cruciate ligaments divided in turn The outward and inward rotations were recorded separately but because of the difficulty of defining accurately an initial or neutral position the total rotation was generally used The neutral position was taken as the position which the knee assumed spontaneously without application of any external force in the outward or inward directions of rotation However this position is particularly unstable after division of the ligaments

The magnitude of the rotational movement especially when the ligaments had

it must be borne in mind that the injuries to the knee joint that commonly occur in accidents are due to a wide variety of factors and seldom correspond exactly to the isolated division of ligaments obtained under experimental conditions It is probable that any particular case involves a complex combination of total and partial division of ligaments and ruptures both to the medial lateral and posterior parts of the capsule It must also be remembered that any instability in extension and flexion can be due to small compression fractures in the condyles which are not disclosed by radiographs

An attempt to make an accurate morphological diagnosis by means of clinical examination of the individual ligaments would seem to involve a certain risk of over schematization even if the information provided by this study is applied

Extensive damage to capsule and ligaments results in greater instability than limited damage and it is probably more logical to classify knee injuries according to the degree of abnormal mobility than to the structures that are believed to be involved

Another problem is whether it is better to treat an actual injury by open surgery or by conservative measures There are several authors that categorically recommend operation However one can see cases of total rupture of ligaments and capsule where an almost normal function has been recovered by conservative therapy There seems to be no entirely valid study that has resolved this problem

SUMMARY

A study was performed of the range of rotation in the knee joint in maximal extension and in the 160 120 and 90 positions This range was also tested after the superficial and deep portions of the tibial collateral ligament had been divided followed by the anterior and posterior cruciate ligaments The study shows that in maximal extension the normal range of rotation in the knee joint is on an average 11 (variation 2–18) Of the different flexion positions tested 120 gave the greatest rotation both for the intact knee and when the various ligaments had been divided in turn With successive division of the ligaments the rotation in this position increased from 29 to 70 the latter value was obtained when the tibial collateral and the anterior cruciate ligaments had been divided division of the posterior cruciate ligament did not increase the range It is conceivable that the range of rotation in the knee-joint in the 120 position is a more sensitive test

for differential diagnosis of isolated ligament injuries than is the usual test of lateral stability.

RÉSUMÉ

Il a été procédé à une étude de l'étendue de la rotation de l'articulation du genou en extension maximum dans les positions de 160, 120 et 90°. Cette étendue a également été vérifiée après la division de portions superficielles et profondes du ligament tibial collatéral suivie de celle des ligaments antérieur et postérieur croisés. Cette étude montre que dans une extension maximum l'étendue normale de la rotation de l'articulation du genou est en moyenne de 11° (variation enter 2 et 18°) dans les différentes positions de flexion examinées. 120° a donné la plus grande rotation tant pour le genou intact qu'après la division des différents ligaments. Par une division successive des ligaments la rotation dans cette position a pu être accrue de 29 à 70°, cette dernière donnée a été obtenue après la division des ligaments tibial collatéral et antérieur croisé; une division du ligament postérieur croisé n'a pas accru l'étendue de la rotation. Il semble que l'étendue de la rotation de l'articulation du genou en position de flexion de 120° fournit un meilleur test pour le diagnostic différentiel des lésions d'un ligament isolé que le test habituel de stabilité latérale.

ZUSAMMENFASSUNG

Eine Untersuchung hinsichtlich des Ausmasses der Rotation im Kniegelenk bei maximaler Streckung und in 160, 120 und 90° Stellungen wurde vorgenommen. Dieses Rotationsausmass wurde auch *geprüft* nachdem der oberflächliche und tiefe Anteil des lig. collaterale mediale und nachher das vordere und rückwärtige Kreuzband durchschnitten waren. Die Untersuchung zeigt, dass bei maximaler Streckung das normale Rotationsausmass im Kniegelenk durchschnittlich 11° (Variation 2–18°) ist. Von den verschiedenen geprüften Beugestellungen gab 120° die grösste Rotation sowohl beim intakten Knie als auch wenn die veschiedenen Ligamente nacheinander durchtrennt worden waren. Mit der aufeinanderfolgenden Durchtrennung der Bänder erfolgte in dieser Stellung eine Zunahme der Rotation von 29 zu 70°. Der letztere Wert wurde erhalten wenn das lig. collaterale mediale und cruciatum anterius durchtrennt waren. Durchtrennung des lig. cruciatum posterius vermehrte das Ausmass der Rotation nicht. Es ist denkbar, dass das Rotationsausmass im Kniegelenk in 120° Beugestellung eine feinere

Probe zur Differentialdiagnose von Bandschäden ist als die gewohnliche Probe auf laterale Stabilität

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EXPERIMENTAL ANKLE-JOINT FRACTURES

By

Carl Hirsch and Jack Lewis

What the clinician sees in the case of an accident is the outcome of a series of events. The interpretation of this result is normally based on the case history, clinical findings and observations at surgery. This information provides the data for a reconstruction of the mechanism of various types of injuries.

Although these analyses are concerned with the biologic course of events in living tissues, they do in fact only reflect the end phase of the action of the forces involved; the intermediate stages are concealed.

There are many reasons, both practical and purely scientific, for trying to understand the relationship between the mechanical force and its response in the tissues. The value of such knowledge in prevention and treatment is self-evident, while problems relating to the physical properties of various tissue elements are perhaps more of a theoretical nature.

In order to approach these problems it is evident that they must be examined by means of some form of model experiment, and as the very nature of the problems concerned with human accidents rules out the use of living subjects, recourse must be had to autopsy specimens.

The study of traumatic effects on autopsy specimens is, of course, subject to many obvious sources of error. The muscles, the circulation and the mechanism of nervous regulation are no longer functioning. On the other hand, it is not certain that these factors necessarily invalidate an experimental approach to carefully defined problems. To a limited extent muscles can be simulated by controlled pullies and circulation can be added to fresh autopsy sections.

It is always possible to compare the experimental results with clinical

Paper presented at the Scandinavian Orthopaedic Association meeting in Helsingfors 1964.

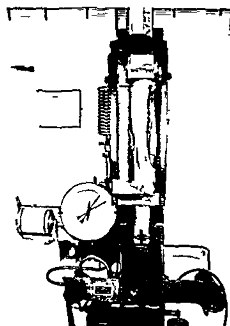


Fig. 1
Experimental arrangement for compression tests on ankle joint in fresh disarticulated autopsy legs. The foot is positioned by various types of wooden plates.

experience and to interpret the results in a clinical context. If the findings in model experiments differ from what we consider we are able or would like to accept, there is usually the opportunity of checking on the clinical cases. This is particularly true of the extent and appearance of the injuries. Model experiments are particularly valuable for studying details which may serve as a guide for clinical verification.

The object in model experiments is to subject parts of the body to mechanical forces and to provide a basis for the study of the action of

Position	kp Force	Fracture
Plantarflexion 45 degrees	725	proximal tibia
"	925	os calcis
"	900	tibial plateau
"	700	tibial plateau
Dorsalflexion 45 degrees	225	talar neck
"	315	talar body
"	160	distal tibia fibula
"	100	distal tibia fibula

Fig. 2
Compression loading flexion injuries

Fracture Lateral Malleolus	Syndesmosis Injury	Deltoid Tear	Fracture Medial Malleolus	Torque kp Meters
+		+		6 4
+	+			6 0
+	+			10 0
+	+		+	8 0
+		+	+	8 4
+		+	+	4 8
			+	10 0

Fig 7
External rotation pronation injuries

Fracture Lateral Malleolus	Syndesmosis Injury	Deltoid Tear	Fracture Medial Malleolus	Torque kp Meters
+	+	+		,6
+		+		6 0
+	+		+	4 0
+			+	4 8
+			+	5 6
+				5 C
				4 0

Fig 8
External rotation supination injuries

The study was performed on fresh autopsy specimens The leg was exarticulated at the knee joint and mounted in specially designed compression units (Figs 1 and 5)

In the first series of experiments (Fig 1) the foot was placed in a given position and the force was applied in the longitudinal direction of the leg The force was increased at a constant rate and its magnitude was read off on a scale The total deformation of the specimen was also recorded When the force no longer increased and the specimen no longer presented any resistance the experiment was discontinued These events were usually accompanied by a traumatic noise Radiographs were taken in two planes before and after the experiments The specimen was then unmounted frozen and dissected for examination of the damage inflicted

Fracture Lateral Malleolus	Rupture Anterior Fibular Talar Ligament	Rupture Fibular Calcaneal Ligament	Fracture Medial Malleolus	Torque kp Meters
	+			7 6
	+			5 6
	+			5 6
	+	+		5 6
	+	+	+	8 0
+				8 0
				5 2
	1			8 8
				6 0

Fig 9
Internal rotation injuries



Fig 10
External r tation without supination or pronation Bimalleolar fracture



Fig 11
External rotation supination spiral fracture of lateral malleolus

The results of the 28 experiments are illustrated in the tables (Figs 2-4)

In the second series the foot was fixed on a movable plate which permitted dorsal and plantar flexion pronation supination and rotary movements (Fig 5) The condyles of the tibia were locked During the course of the experiment the specimen was loaded with a constant



Fig 12
Internal rotation Rupture of anterior talofibular ligament and fibular calcaneal ligament



Fig 13
Internal Rotation Anterior fibular talar ligament avulsed from talus



Fig 14
External rotation supination Fracture medial malleolus with posterior tibial tendon trapped



Fig 15
Internal rotation Rupture of anterior fibular talar ligament and fibular calcaneal ligament



Fig 16
Internal Rotation Peroneus longus tendon trapped within the ankle joint

weight usually body weight The loading could be varied at will in different experiments The force applied in the rotational movement was read off on a spring balance These specimens too were radiographed before and after the experiment After freezing they were dissected for analysis of the damage

The results of these 35 experiments are presented in Figs 6–9

Figs 10–12 illustrate some radiographs taken just as the experiment was discontinued

Figs 13–16 show examples of damage to soft tissues

DISCUSSION

The damage to the joint capsule ligaments tendons and skeletal tissue seen in these experiments does not in itself bring forward any new findings Attention centres rather on the distribution and extension of the injuries in the series of specimens There is today a tendency in many centres towards open reduction and reconstructive surgery in ankle lesions Although it seems to be attractive it is still too early to assess the value of extensive surgical repair with respect to the long term result Surgery has of course its technical limitations as far as the capsule and ligaments are concerned The tendency to choose this form of treatment has however the advantage that the extent and frequency of the injuries can be better recorded and the results appreciated with regard to different kinds of injuries For such purpose even experiments on autopsy specimens may be justified as a guidance

They may also serve as a method for classification of ankle joint injuries The experiments presented do not seem to support fully earlier

interpretations. The anatomical appearance does not explain the mechanism of trauma and does not permit terms of injuries expressed by force direction.

SUMMARY

In the experimental studies performed, the following conclusions were reached:

1. Whenever forces act against normal ankle unit function, multiple lesions are likely to occur.

2. In ankle injuries a medial and lateral component are frequently present, sometimes consisting of bilateral bone lesions, a bone lesion and an opposing soft tissue lesion, or bilateral soft tissue lesions.

3. More soft tissue injury is present than is usually expected.

4. Simultaneous lesions occur more frequently than serial ones.

5. Forces that coincide with normal ankle function are well tolerated.

6. In compression loading the ankle can tolerate large forces, failure occurring proximal or distal to the ankle.

7. The force required for internal or external rotational injuries is small.

RÉSUMÉ

Dans les études expérimentales pratiquées, on arrive aux conclusions suivantes:

1. Lorsque des forces s'opposent à la fonction normale de la cheville, des lésions multiples peuvent apparaître.

2. Dans les lésions de la cheville, un composant médial et latéral sont fréquemment observés, consistant parfois en des lésions bilatérales de l'os, une lésion osseuse et une lésion opposée des tissues mous, ou des lésions bilatérales des tissues mous.

3. Généralement il y a plus souvent une lésion des tissus mous qu'on ne l'aurait cru.

4. Des lésions simultanées se produisent plus fréquemment que des lésions en série.

5. Les forces qui coïncident avec la fonction normale de la cheville sont bien tolérées.

6. Dans la charge de compression la cheville peut tolérer de grandes forces, le défaut apparaissant proximalement ou distalement à la cheville.

7. Les forces requises pour des lésions de rotation interne ou externe sont peu importantes.

ZUSAMMENFASSUNG

Durch die ausgeführten experimentellen Studien gelangte man zu folgenden Schlussfolgerungen

1 So oft Krafte auf eine normale Knocheleinheitsfunktion einwirken kommt es wahrscheinlich zu vielfachen Schädigungen

2 Bei Knöchelschäden ist häufig eine mediale und laterale Komponente vorhanden die manchmal in einer doppelseitigen Knochenbeschädigung einer Knochenbeschädigung und einer anderesseitigen Weichteilbeschädigung oder eine doppelseitigen Weichteilbeschädigung besteht

3 Eine ausgedehntere Weichteilbeschaidgung als man gewohnlich annimmt ist vorhanden

4 Gleichzeitige Schädigungen entstehen haufiger als auseinander folgende

5 Krafte die mit normaler Knochelfunktion zusammenfallen werden gut vertragen

6 Bei Kompressionsbelastung kann der Knochel grosse Krafte ertragen Ein Schwichten tritt nur proximal oder distal vom Knochel auf

7 Die Kraft welche notwendig ist um Auswarts oder Einwarts rotationsschäden zu erzeugen ist nur gering

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From the Biomechanics Laboratory Department of Orthopaedic Surgery
University of Gothenburg Sweden (Head Prof Carl Hirsch M D)

IN VIVO DISCOMETRY IN LUMBAR DISCS WITH IRREGULAR NUCLEOGRAMS

Some Differences in Stress Distribution between Normal and Moderately Degenerated Discs

By

ALF NACHEMSON

Disc degeneration in the lumbar spine is often discussed in terms of mechanical factors inasmuch as they have been partially implicated in the etiology of morphological changes observed (1 4 5 8 9 16)

Clinically the lumbar discs are mostly judged from standard radiograms of the lumbar spine and the roentgenographic changes interpreted as disc degeneration in the lumbar spine have been defined (10 18) However it has also been demonstrated by *Friberg & Hirsch* (5) that the degenerative changes inside the disc can exist in spite of a normal roentgenogram Since disc degeneration in the lumbar spine also has been connected with symptoms of low back pain disorders (3 7 8 9) other procedures e g disc puncture (*Hirsch*) (6) and discography (*Lindblom*) (11) have been added to the clinical and roentgenographic examination in patients with low back pain

Today discography or nucleography is a relatively frequently used procedure When the nucleus pulposus shows a round smooth edged appearance without communications to the outside of the disc it is regarded as normal (Fig 1) If the nucleogram shows irregularities in its boundary with the annulus fibrosus or the vertebral endplate and if the contrast medium penetrates through the annulus fibrosus the disc has been said to be degenerated (2 3 11) (Figs 2 and 3) *Erlacher* (2) classified the nucleographic picture in five different groups It should be mentioned however that no definite knowledge exists as to the macroscopic anatomic equivalents of the irregular nucleograms

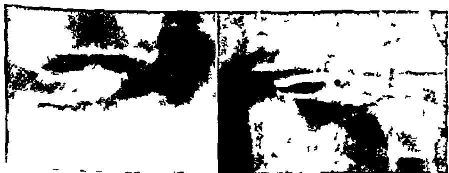
Discometry is a method that evaluates the pressure inside lumbar



Fig 1
Normal discogram after completion of measurements



a



b

Fig 2
Examples of nucleograms showing m d rate degeneration of the nucleus pulposus
Some fragmentation is seen as well as the needle track

A Case No 6 (Male age 34 y)
B Case No 10 (Male age 40 y)

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a



b

Fig 2
Example f nucle(gram h wing m derate d generation of the nucleus pulposu Some fragmentation i e n a well as the needle track.

A Case No 6 (Male age 34 y)
B Case N 10 M le age 40 y)



Fig. 3

Examples of nucleograms showing moderate degeneration of the nucleus. In these discs the extent of fragmentation is more pronounced than in Fig. 2. A fissure can also be seen in the annulus fibrosus (B).

A. Case No. 7 (Male age 42 y.)
B. Case No. 9 (Male age 29 y.)

discs. This method was developed in autopsy material and was shown to be completely valid only in normal or slightly degenerated discs as these discs were shown to have hydrostatic properties (12). Microscopic examination alone was used to classify whether the disc was normal or not.

After the method had been established in post mortem material studies were extended to living subjects (14, 15). The results of the *in vivo* tests could be categorized into three groups relative to the pressures recorded when these were related to the size of the disc and the *body weight of the patient*.

In the first group the pressures were highest and the nucleogram performed at the completion of measurements was normal. In the second group the stresses recorded were lower and the nucleograms all showed some fragmentation of the nucleus and occasional fissure

TABLE 1
Summary of Data on Subjects

Case No	Age yr	Sex	Weight kg	Height cm	Disc Level	Disc Condition	History
1	58	♂	66.8	165	L3	Mild degen.	Low back pain for 6 yrs
2	53	♂	80.3	170	L3		Lumb. scoliosis due to short leg. Low back pain
3	43	♂	58.7	180	L3		Fusion L4 S1. Back pain
4	39	♀	95.0	165	L4	..	Low back pain and sciatica
5	43	♀	64.0	173	L2		Mild low back pain 3 months
6	34	♂	7[illegible].6	180	L3		Low back pain for 2 weeks
7	42	♂	80.0	179	L3		Low back pain for 6 months
8	40	♂	83.0	184	L3		Low back pain for 7 months
9	[illegible]	♂	74.5	183	L3		Low back pain for 2 months
10	40	♂	81.0	180	L3		Mild low back pain 3 weeks

TABL

Stresses Obtained in Moderately Degenerated Dis

Case No	Disc area cm	Disc level	Part of body wt above level kg	Sitting unsupp upright	Sitting Valsalva maneuver	Sitting corset inflated	Sitting 9 1 kg in hands
1	17 7	L3	39 1	6 9	7 7		7 4
2	18 1	L3	45 8	9.2	10 2	4 2	13 0
3	15 0	L3	33 2	8 5			12 8
4	15 8	L4	50.2	11.3	11.3	7 7	14 4
5	16 3	L2	35 2	7 4			
6	20 4	L3	41 4	7 7			
7	17 5	L3	45 6	12 8			
8	21 1	L3	47.3	6 7			
9	17 8	L3	42 5	7 4			
10	22.2	L3	46 2	4 9			

31 8 kg added † 10 forward leaning only According to *Ruff* (17)

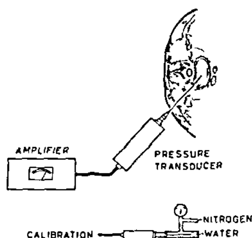


Fig 5

Schematic drawing of the method used in intravital disc pressure measurements (discometry) The manner by which the needle is inserted is also demonstrated

formation in the annulus Repeated measurements in these individuals yielded reproducible results

In the third group the pressure recordings were lowest and varied considerable and were non reproducible In this group the nucleograms showed marked irregularities and fissures in the annulus fibrosus

. r Vari us Conditions (in Kg per cm²)

Sitting 22.7 kg in hands	Sitting forward leaning 20	Sitting forward leaning 10 kg in hands	Sitting forward leaning 20 kg in hands	Reclining tilted on side	Standing upright	Standing forward leaning 20
12.1*						
15.5				0		
16.3				7 0		
19.0				5.8		
	8 7	10.9	13 4	5.3	6.3	8 1
	9.2*	10.2*	12 7*			
	8 8					
	13 0	15 1	18 0	3.5	5.8	10 6

The results of the discometry studies in the first group have been previously reported (15) This report presents the results of intravital discometry in discs where the nucleogram showed some fragmentation and/or a fissure in the annulus and in which the recordings were reproducible

METHOD

The method by wich the stresses are evaluated has been reported elsewhere (12 15) It is based on the fact that the nucleus pulposus acts on a membrane-covered water filled needle having a rectangular hole in its side Th s needle is connected to a pressure transducer (Fig 4) Before and after each experiment the needle is calibrated against known pressures By the use of the roentgen image intensifier it is easy to locate the disc t be tested The needle is inserted in L 2 L 3 or L 4 discs from the side It should be noted that each stre s value recorded is a mean from three consecutive measurements where each single measurement has not deviated from the mean more than comparable recordings in the fully normal discs (15)

MATERIAL

Ten subject whe e the nucleograms fulfilled the criteria outlined were studied The vital data ummarized in Table 1 The sul jects were tested in different positi ns due part to technic l circum tanc an l al o to the fact that the subjects were lu ted at different period wh n n the ther special position was being stud d These data are pre ente l n l ble ?

RESULTS

Sitting Position

As seen from Table 2 the stresses measured ranged from 5 to 13 kg/cm in the sitting position used in the studies i e straight upright sitting with arms resting along the sides of the body and without back support

On average the stresses measured were 30 per cent less than would have been expected for an individual of the same size and with the same cross sectional area of the disc but with a normal nucleogram (Table 3)

From values obtained with weights in the hands both upright and leaning forward it is obvious that even in these discs with somewhat irregular nucleograms the stresses increase in the same manner as was noted in discs with normal nucleograms (14)

Standing Position

The results tend to confirm earlier observations on nucleographically normal discs that the stress inside the discs and accordingly the load on the disc decreases by about one third as compared to the sitting position used (Table 2) The stresses obtained in the discs reported here were as in the sitting position about 30 per cent less than might be expected

Reclining Position

The five measurements performed in reclining position (lateral decubitus) also showed lower values of stress in these discs than in nucleographically normal discs Compared to the values recorded in the same discs in the sitting position a decrease averaging 50 per cent was noted (Table 2) The same observation was made earlier (15)

DISCUSSION

In autopsy studies it was shown that even when the disc was classified as somewhat degenerated at macroscopic examination the nucleus still retained its hydrostatic properties (12) These discs showed some fibrosis in the nucleus and/or isolated fissures in the annulus It appears that such changes exist in the discs presented here where the nucleograms showed irregularities and the results were reproducible These results therefore can be regarded as obtained from discs with macroscopic degenerative changes probably however of a mild degree

TABLE 3

Stresses Obtained in moderately Degenerated Discs Compared with Expected Values of Disc Pressure in Normal Discs

Upright sitting position

Case No	Stress measured kg/cm	Disc area cm²	Bodyweight above level measured kg	Total load kg	Load on disc kg/cm	Approx pressure in a normal disc kg/cm	Decrease in stress in deg. disc as compared to normal %
1	6.9	17.7	38.1	136.7	7.7	11.6	41
2	9.[illegible]	18.1	45.8	158.2	8.7	13.1	30
3	8.5	15.0	33.2	1[illegible]3.0	8.2	1[illegible].3	30
4	11.1	15.8	60.2	170.6	10.8	1[illegible].2	30
5	7.4	10.3	35.2	1[illegible]8.0	7.[illegible]	11.[illegible]	38
6	7.7	[illegible]0.4	41.4	145.9	7.[illegible]	10.7	[illegible]8
7	1[illegible].8	17.5	45.0	167.7	[illegible].0	13.5	5
8	6.7	[illegible]1.1	47.3	1[illegible]4	7.7	11.[illegible]	4
9	7.4	17.8	4[illegible].5	149.0	8.4	1[illegible]	11
10	4.[illegible]	[illegible]	46.[illegible]	159.4	7.[illegible]	10.8	5[illegible]
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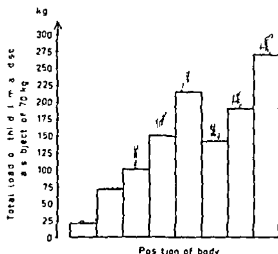


Fig 5

Total load on the third lumbar disc in different positions in a subject weighing 70 kg Positions shown are 1) reclining (relaxed supine) 2) reclining (lateral decubitus) 3) standing upright 4) standing + twenty degrees forward leaning without and 5) with 20 kg load in arms 6) sitting upright arms and back unsupported 7) sitting + twenty degrees forward leaning without and 8) with 20 kg load in arms

TABLE 4

Approximate Formulas for Load (I) on Lumbar Discs in Different Positions

I_O = intrinsic pressure W = weight above the level measured
(59% of bodyweight above L IV 57% above L III and 55% above L II)

Position		
Upright sitting with arms and back unsupported	$I_{sitt} = I_O + 2.8W$	$I_O \approx 30$ kg
Upright standing	$I_{stand} = I_O + 2.1W$	$P_O \approx 15$ kg
Reclining (tilted on side lateral decubitus)	$I_{rec.l} = \frac{I_O + 2.8W}{2}$	$P_O \approx 30$ kg
Reclining (relaxed supine)	$I_{rel} = I_O$	$P_O \approx 15$ kg
Sitting + forward leaning α degrees	$I_{sit} = P_O + 2.8W + 3.6W \sin\alpha$	$P_O \approx 30$ kg $\alpha = 10$–20
Standing + forward leaning α degrees	$I_{stand} = I_O + 2.1W + 3.6W \sin\alpha$	$P_O \approx 15$ kg $\alpha = 10$–20

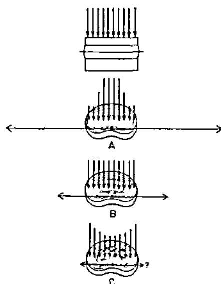


Fig 6
Relative relationship between load on the lumbar disc per unit of area and the vertical and tangential stresses on the annulus fibrosus
A Normal disc
B Moderately degenerated disc
C Severely degenerated disc (Hypothetically cannot be measured with the present method)

From the discometry studies in discs with normal nucleograms the approximate relationship between the body weight of the subject his position and the total load on the disc could be delineated (Fig 5) (14 15) These relationships are tabulated in Table 4

In Table 3 the stresses measured in the sitting position in subjects with moderately degenerated discs is shown The total load on the disc is calculated according to the formula given in Table 4 Dividing this load by the cross sectional surface area of the disc the load on the disc per unit of area can be obtained It is seen in Table 3 that this load per unit of area is approximately equal to the stress measured inside these discs

In the normal discs it was found that the pressure measured in the nucleus pulposus is 1 5 times the load applied per unit of area (12 13) In discs with irregular nucleograms the stress measured under intra vital conditions is equal to the load on the disc per unit of area (Table 3) This implies that one effect of a moderate degeneration seems to be a decrease of about 30 per cent of the intradiscal stress

From earlier studies (12 13) on autopsy specimens a relationship between the pressure or stress in the nucleus pulposus and the vertical and tangential tensile stresses in the dorsal part of the annulus fibrosus was established (Table 5 Fig 6) In macroscopically normal lumbar discs taken at autopsy the width is approximately 6 mm In these discs

TABLE 5

Approximate Relationship between Load per Unit of Area (p) on the Disc and the Intradiscal Pressure Measured (p_n)

Normal discs	$p_n = 1.5p$
Moderately degenerated discs	$p_n = p$

Approximate Relationship between Vertical Load on the Annulus Fibrosus (p_a) and the Vertical Load per Unit of Area (p) in the Disc

Normal discs	$p_a = 0.5p$
Moderately degenerated discs	$p_a = p$

Approximate Relationship between the Tangential Tensile Stress in the Dorsal Part of the Annulus Fibrosus (τ_{td}) and the Load per Unit of Area on the Disc (p) and the Intradiscal Pressure (p_n)

Normal discs	$\tau_{td} = 4p = 2.7p_n$
Moderately degenerated discs	$\tau_{td} = 2p = 2p_n$



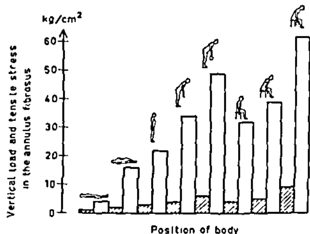


Fig 7

Vertical load per unit of area on the annulus fibrosus and tangential tensile stress in the dorsal part of the annulus in a normal third lumbar disc in a subject weighing 70 kg and assuming the positions schematically shown (see Table 6). In the moderately degenerated disc the vertical stress will increase by 100 per cent and the tangential tensile stress decrease by 50 per cent.

the tangential tensile stresses (σ_{td}) could be calculated from the expression

$$\sigma_{td} = 4\,p$$

where p is the load per unit of area on the disc (Table 6)

In the normal discs the vertical load on the annulus was found to be only 50 per cent of the applied load per unit of area on the disc In the moderately degenerated discs presented here however where the stress inside the nucleus has decreased by one third as compared to normal discs the vertical load on the annulus will be about the same as that applied on the disc per unit or area (Table 6)

TABLE 6

Approximate Vertical Load and Tangential Tensile Stress in the Dorsal Part of the Annulus Fibrosus in a Subject Weighing 70 kg with a Moderately Degenerated Third Lumbar Disc Having Cross Sectional Area of 17.5 cm² Comparable Values in a Normal Disc are Given

Position of body	Moderately degenerated		Normal	
	Vertical load kg/cm	Tensile stress kg cm	Vertical load kg/cm	Tensile stress kg cm
Upright sitting unsupported	8	16	4	32
Upright standing	6	11	3	22
Reclining (lateral decubitus)	4	8	2	16
Reclining (relaxed supine)	2	[illegible]	1	4
Sitting + forward tilting of 20	10	[illegible]	5	44
Sitting + forward tilting of 20 and 10 kg load in each hand	15	31	8	62
Standing + forward tilting of 20	8	1	4	34
Standing + forward tilting of 20 and 10 kg load in each hand	12	4	6	49

Using the established equations (Tables 4 and 5) the approximate vertical load and tangential tensile stress on the dorsal part of the annulus fibrosus in subjects of different weights can be calculated for normal lumbar discs (Fig. 7).

This can be done also in the present material and it can be shown that moderate degeneration probably implies an increase by about 100 per cent for the vertical load on the annulus fibrosus while the tangential tensile stresses decrease by 50 per cent when compared to the normal discs. Thus the change in stress distribution that occurs in lumbar discs with irregular nucleograms can be mathematically expressed. Schematically this is visualized in Fig. 6. In Table 6 these stresses have been calculated for lumbar discs of equal size with normal and irregular roentgenograms in a subject of 70 kg.

As was mentioned it is very likely that the material presented here, discs with nucleograms showing some irregularities, is comparable to the microscopic picture of moderate degeneration, *i.e.* some fibrosis in the nucleus and an occasional fissure in the annulus. The reason for the lower stress values obtained in these discs where hydrostatic properties still exist might be either that the substance of the nucleus pulposus has changed so that it is now more easily compressible or else that the stiffness of the annulus fibrosus has increased, *i.e.* in the normal discs the annulus is more easily compressed vertically than in the degenerated discs.

SUMMARY

Results are reported from intravital discometry in ten individuals where the lumbar discs measured showed some fragmentation of the nucleus and an occasional fissure in the annulus fibrosus in the nucleogram performed at the completion of measurements. Since no definite knowledge exists as to the microscopic anatomic equivalent of defined nucleograms it is for the moment impossible exactly to evaluate the *degree of degeneration of the discs in this material*. For reasons discussed in the paper the present material most likely represents lumbar discs with macroscopically moderate degeneration.

Moderate degeneration in the lumbar disc seems to lessen the internal stress by about 30 per cent as compared to the pressures obtained in nucleographically normal discs of equal sizes and in individuals of the same body weight.

The values obtained in the unsupported upright sitting position have been around 10 kg/cm^2 (5–13 kg/cm^2). Recordings in subjects holding

weights with and without forward leaning showed increases of the stresses in the same manner as was observed in the normal discs.

In the standing and reclining positions studied the values recorded implied a decrease of 30 and 50 per cent respectively as compared to the sitting position used. The same decrease in pressure was noted in normal discs.

Moderate degeneration in a lumbar disc will change the distribution of stress compared to a normal disc so that the vertical load on the dorsal part of the annulus fibrosus will increase by 100 per cent while the tangential tensile stress in the same part will decrease by 50 per cent.

It could be calculated that the vertical load on the annulus fibrosus in a man of 70 kg having a moderately degenerated third lumbar disc would be 10 kg/cm in the 20 forward sitting position as compared to 5 kg/cm were the disc normal.

The tangential tensile stress in the dorsal part of the third lumbar disc in such a subject would be about 30 kg/cm if the disc was moderately degenerated and about 60 kg/cm were the disc normal.

Increased compressibility of the nucleus pulposus and/or increased stiffness in the vertical direction of the annulus fibrosus in these discs as compared to nucleographically normal ones might account for the lower values of stress obtained in the nucleus pulposus.

RESUME

Sont rapportes les resultats de discometrie intravitale chez 10 individus ou les disques lombaires mesures montraient une fragmentation du noyau et une fissure occasionnelle de l'anneau fibreux sur le nucleogramme pratique pour compléter les mensurations. Etant donne que l'on n'a pas des connaissances definitives sur l'equivalence anatomique macroscopique de nucleogrammes determines, il est pour le moment impossible d'evaluer exactement le degre de degeneration des disques dans ce materiel d'observation. Pour des raisons donnees dans cette étude, le present materiel d'observation présente probablement des disques lombaires avec une degeneration macroscopique moderee.

Une dégénération moderee du disque lombaire semble diminuer la tension interne d'environ 30 pour cent par comparaison avec la pression obtenue dans les disques nucleographiquement normaux d'egale grandeur chez des individus ayant le même poids du corps.

Les valeurs obtenues dans la position assise redressee sans support

ont été d'environ 10 kg/cm² (5–13 kg/cm²). Des enregistrements chez des sujets tenant des poids en position inclinée en avant ou non montrent une augmentation de la tension de la même manière que celle observée pour les disques normaux.

Dans les positions verticale et couchée, l'étude des valeurs enregistrées *montre une diminution de 30 à 50 pour cent respectivement* comparées à la position assise utilisée. La même diminution de la pression dans les disques normaux a été constatée.

Une dégénération modérée du disque lombaire change la distribution de la tension par rapport aux disques normaux de sorte que la charge verticale sur la partie dorsale de l'anneau fibreux augmente de 100 pour cent, alors que la force tangentielle de tension diminue de 50 pour cent environ dans la même partie.

On a pu calculer que la charge verticale sur l'anneau fibreux chez un homme de 70 kg ayant le 3ème disque lombaire légèrement dégénéré serait de 10 kg/cm² en position inclinée en avant de 20°, par comparaison à 5 kg/cm² pour un disque normal.

La tension tangentielle dans la partie dorsale du 3ème disque lombaire chez un tel sujet serait de 30 kg/cm² si le disque est légèrement dégénéré et approximativement de 60 kg/cm² si le disque est normal.

Une compressibilité accrue du noyau fibreux et/ou une rigidité accrue en direction verticale du noyau fibreux dans ces disques, par comparaison avec ceux nucléographiquement normaux, peut provenir des valeurs inférieures de tension obtenues dans le noyau pulpeux.

ZUSAMMENFASSUNG

Über Ergebnisse intravitaler Diskometrie an zehn Personen, bei denen die gemessenen lumbalen Zwischenwirbelscheiben etwas Fragmentierung des Nucleus und gelegentlich eine Fissur des Annulus fibrosus im Nukleogramm, das bei der Vollendung der Messungen ausgeführt wurde, zeigten, wird berichtet. Da keine sichere Kenntnis hinsichtlich des makroskopisch-anatomischen Äquivalentes eines Nukleogramms besteht, ist es zur Zeit unmöglich, den Grad der Degeneration der Zwischenscheibe in diesem Material zu bestimmen. Aus Gründen, die in der Arbeit besprochen werden, stellt das vorliegende Material höchst wahrscheinlich lumbale Zwischenscheiben mit makroskopisch moderater Degeneration dar.

Moderate Degeneration in der lumbalen Zwischenwirbelscheibe scheint die innere Spannung um ungefähr 30 Prozent zu vermindern im

Vergleich zu den Druckwerten die man in nukleographisch normale Scheiben von gleicher Grosse und bei Personen gleichen Korpergewichtes erhalt

Die Werte die bei nicht unterstützter aufrecht sitzender Stellung erhalten wurden bewegen sich um 10 kg cm (5–13 kg cm) Aufzeichnungen an Personen die Gewichte hielten mit und ohne Vorwarts beugung zeigten eine Zunahme der Druckwerte in derselben Weise wie sie bei normalen Scheiben beobachtet wurde

Bei der Untersuchung in stehender und liegender Stellung wiesen die aufgezeichneten Werte auf eine 30 Prozent beziehungsweise 50 Prozent Abnahme hin Dieselbe Abnahme des Druckes wurde bei normalen Scheiben bemerkt

Massige Degeneration einer Lendenwirbelzwischenscheibe wird die Druckverteilung im Vergleich mit der normalen Scheibe verandern u.zw derartig dass die vertikale Belastung am dorsalen Teil des Annulus fibrosus um 100 Prozent zunehmen wird wahrend der tangentiale Spannungsdruck derselben Region um 50 Prozent abnehmen wird

Man konnte ausrechnen dass die vertikale Belastung auf den Annulus fibrosus bei einem 70 kg schweren Mann mit mässig degeneriertem drittem Lendendiskus 10 kg cm bei 20 vorwärts geneigter Stellung sein wurde wahrend sie nur 5 kg cm beim normalen Diskus sein würde

Der tangentiale Spannungsdruck im dorsalen Teil der dritten Lendenscheibe einer solchen Person würde ungefähr 30 kg cm sein wenn der Diskus moderat degeneriert ware und ungefähr 60 kg cm wenn er normal sein wurde

Erhohte Zusammendruckbarkeit des Nucleus pulposus und/oder vermehrte Steifheit des Annulus fibrosus dieser Zwischenscheiben in der vertikalen Richtung konnen im Vergleich mit nukleographisch normalen Disken fur die niedrigen Druckwerte im Nucleus pulposus verantwortlich gemacht werden

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A CASE OF FIBROUS DYSPLASIA (JAFFE–LICHTENSTEIN) WITH VERTEBRAL FRACTURE AND COMPRESSION OF THE SPINAL CORD

By

MAGNUS ROSENCRANTZ

The concept of fibrous dysplasia was introduced in 1938 by *Lichtenstein* In a survey *Jaffe & Lichtenstein* in 1942 described the disease as "a condition affecting one several or many bones the graver cases of which may present abnormal pigmentation of skin premature sexual development hyperthyreoidism or still other extraskeletal abnormalities

The lesions may occur in any bone the monostotic preferably in the ribs and jaws the polyostotic most commonly in the femur the tibia the pelvis and the humerus Lesions in the vertebral column are according to the most experienced authors infrequent (*Jaffe Lichtenstein Uehlinger)* and the absence of such lesions has even been regarded as a diagnostic criteria (*Uehlinger*) Reviewing the literature the author has found 29 cases with vertebral lesions out of about 300 cases of fibrous dysplasia so far reported In most cases the lesions were to be found in the thoracic spine Symptome from the spinal cord or nerve roots occurred in 8 of the 29 cases usually with varying degrees of paraplegia In three of these cases there were compression fractures (*Teng et al Skanse et al Jirout Lewit*) In the remaining five cases the symptoms were caused by expansion of either a vertebral body or of pedicles and articular processes (*Rosendahl Jensen Lecocq Ledoux Lebard Jaffe*)

The author has had the opportunity of following a case of polyostotic fibrous dysplasia an 18 year old boy who in 1954 at the age of 8 sustained a fracture of the right distal humerus and two years l refractur A cystic expansion of the bone in the region of the



Fig 1



Fig 2

Fig 1 Right angle gibbus at the level of the D6 vertebra of which only a small wedge shaped fragment remains In the posterior parts of the vertebral bodies of D7 and D8 solitary well demarcated rounded radiolucenses are seen (tomographs)

Fig 2 Gas myelography (cisternal puncture) Partial block at the level of the compressed vertebra (tomography)

gave rise to a radiologic examination of the entire skeleton revealing changes in the skull several ribs the right scapula and both hands At this time there were no signs of vertebral lesions During the following years he was free of symptoms but in 1961 increasing pain in the thoracic spine and a gibbus developed In June 1962 within a few days weakness appeared in the lower extremities there was sensory loss over the lower part of the trunk and both legs and urinary retention

On admission in October 1962 examination disclosed a normally developed 16 year old boy with a severe upper thoracic gibbus There was paraplegia with diminished sensation which varied for different modalities up to the D6 segment

Radiologic examinations Figs 1–3 In addition to those in the vertebrae and the skull there were changes in several ribs bilaterally in



Fig 3
Sclerotic thickening of the external table of the right occipital and the sphenoid bone

the manubrium in the right scapula and humerus and in most of the metacarpals and phalanges of both hands

The blood chemistry was normal

In spite of unchanging radiographic status all signs of spinal cord compression entirely disappeared on conservative treatment consisting of bedrest and a plaster cast To prevent recurrence a posterior spinal fusion (Albee Hibbs) with a cortical graft was made in February 1963 Microscopic examination of bone tissue removed at the operation confirmed the diagnosis of fibrous dysplasia

At a radiologic examination one year after the operation the patient was still free of symptoms and the bone graft was shown to be completely resorbed The angulation of the spine had increased (Fig 4) With the exception of those in the humerus (Fig 5) the other skeletal lesions were unchanged A small exploratory incision over the easily palpable humeral expansion revealed a very thin cortex covering a huge cyst filled with yellowish fluid

When last seen in May 1964 the patient was still free of symptom and the radiologic appearance of the lesions remained unchanged



Fig 4



Fig 5

Fig 4 Increased angulation of the spine with the D5 vertebra resting on anterior surface of D7

Fig 5 Loculated cyst like exspansion with extreme thinning of the cortex in the ventro lateral part of right distal humerus

DISCUSSION

The isolated bone lesions in fibrous dysplasia are with the exception of those occurring in the skull radiographically not characteristic Cyst like lesions in the diaphyses of the long bones or in flat bones should give rise to an examination of the entire skeleton including the skull In this case the diagnosis was based on the presence of multiple cyst like expansive bone lesions sparing the epiphyses having a mainly unilateral extension in an otherwise normal skeleton of a growing individual and coexisting with a sclerotic thickening of certain skull bones New manifestations of the disease may as illustrated by the present case appear until the closure of the epiphyses The early diagnosis and treatment of lesions which could conceivable give rise to complications such as fractures or pressure on adjacent tissues are of prime importance In this severely complicated case surgery seems

to have added nothing to the beneficial effect obtained by conservative treatment

SUMMARY

A case of fibrous dysplasia with paraplegia caused by lesions in the thoracic spine and successfully treated with immobilization and bone grafting is presented The localization of the disease to the vertebral column is infrequent but a review of the literature suggests more common occurrence than previously stated The radiographic appearance of the lesions is discussed and the importance of early diagnosis and observation is stressed

RESUME

Il est rapporte un cas de dysplasie fibreuse avec paraplegie causee par des lesions dans la colonne thoracique et traité avec succes par l immobilisation et une greffe osseuse La localisation de la maladie dans la colonne vertebrale n est pas frequente mais apres avoir passe la litterature en revue l auteur estime qu il convient d envisager que le pourcentage de ces cas est superieur a celui que l on avait prevu jusqu ici Il est discute de l appearance radiographique des lesions et l importance d un diagnostic et d une observation precoces sont soulignes

ZUSAMMENFASSUNG

Ein Fall von fibroser Dysplasie mit Paraplegie hervorgerufen durch Ergriffensein der Brustwirbelsäule und erfolgreich mittels Ruhigstellung und Knochentransplantation behandelt wird vorgestellt Die Lokalisation der Erkrankung in der Wirbelsaule ist selten aber der Verfasser meint nach Durchsicht der Literatur dass sie doch haufiger vorkommt als fruher festgestellt wurde Das Erscheinen der Erkrankung im Rontgenbilde wird besprochen und die Wichtigkeit der frühzeitigen Diagnose und Beobachtung wird hervorgehoben

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From the Clinic for Cerebral Palsy
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SURGERY OF THE HAND IN CEREBRAL PALSY

By

J Mortens

Many operative procedures have been suggested to improve the function of the spastic hand The aim of this paper is to analyse critically the different interferences possible based upon the literature and upon a limited personal experience

The Cerebral Palsy Clinic at the Orthopaedic Hospital Copenhagen was opened in 1950 and treatment was instituted on a team basis 1500 patients were seen at the clinic up to 1961 and 290 patients were operated upon by the orthopaedic surgeon of the team with 800 individual operations —With regard to the hand 17 patients and 17 hands were operated on with 54 individual operations

When the clinic opened according to the fashion at that time few operations were performed With physiotherapy and braces instituted early and continuously employed it was hoped to improve motor function satisfactorily and only organic contractures in neglected cases and very severe spasticity gave indications for operations—a reaction to the previous period in which training was neglected and the results of operations accordingly were considered unsatisfactory However gradually many of the previous conventional operative procedures came into use again and new types of operations were employed as experience was gained as to what extent physiotherapy and splinting alone were inadequate and to what extent the individual operative procedures were helpful when pre and postoperative training and many years of observation were possible

We have adopted a moderate approach to early soft tissue surgery in Cerebral Palsy in order not only to correct deformities but also to the extent possible for us to correct the imbalance of muscle pull by surgery in the prevention of recurrences of the deformities to improve dynamic function and to facilitate the task of training for the physio-

therapists and occupational therapists and in order to diminish the need for splints and braces.

The reason for this approach is the fact that alteration in muscle lengths and deformed bone growth in the presence of muscle imbalance beset the treatment of the deformity and dysfunction in spastic paralysis as well as in poliomyelitis. If muscle imbalance is not corrected by early soft tissue operations in addition to splinting and physiotherapy it is likely that the deformity and dysfunction will progress to a greater degree in the growing child.

TABLE 1

Orthopaedic Operations to Improve Function of the Hand in 17 Patients

Myo tenotomies or Elongation of Tendons	pronator quadratus	2	
	Wrist flexors	7	
	add poll interos dors I	2	
	flex poll long	1	12
Tendon transplantations			
A	pronator teres to ext carpi rad	5	
B	flex carpi ulnar		
	1) dorsal to radius or to ext carp rad	5	
	2) to ext dig com	4	
C	flex carpi rad to		
	1) ext poll long	5	
	2) abd poll long	2	21
Ten desc	sublimis – interphal prox	6	6
Arthrodeses	radio-carpal	11	
	metacarpo phal I	3	
	carpo – metacarpal I	1	15
Total			54

During the years when we have gradually extended the employment of operative procedures we have also become increasingly interested in the problem of improving the function of the spastic hand by surgery. But due to the experience gained during the years in the whole field of Cerebral Palsy (*Mortens* 1962, 1965) we are still of the opinion that only procedures with the most elementary objectives yield consistently

good or fair results And this attitude we have hitherto also extended to the field of surgery of the spastic hand Our aim at present is to stop and take stock of the position to see whether our attitude is too conservative and to consider if we might be justified in altering our opinion that some suggestions for operative procedures in the literature are rather theoretical

In our clinic 7 per cent of the individual operations performed have been to improve function of the spastic hand or rather 6 per cent if the number of patients operated upon is the basis for the relative frequency of operations on the hand This frequency varies to some extent in the literature

Green (1942) reports 10 per cent *McCarroll* (1949) 13 per cent *Goldner* (1955) 4 per cent and *Swanson* 4 per cent

The individual procedures we have used can be seen from Table 1 On all hands more than one individual operation was performed as a combined operation often several combined operations were performed at the same operative session or with some months interval

The age of the patients when operated varied between 12 and 23 years

The type of Cerebral Palsy was in most cases spastic hemiplegia but three had a spastic tetraplegia one of these mixed with athetosis

The deformity and dysfunction to be corrected in order to improve function can be grouped under three headings 1) the pronation contracture of the arm and hand 2) the flexion contracture of the wrist and the imbalance between finger flexors and extensors and 3) the adducted and flexed position of the thumb

ad 1) We have employed myotenotomy of the pronator quadratus and transposition of the pronator teres to the radial wrist extensors—directly or indirectly through the interosseous membrane round the ulnar side of the radius—in the hope of abolishing pronation contracture A strong spastic ulnar wrist flexor was also transferred dorsally to the radial wrist extensors or if a wrist fusion was performed dorsally to the radius The immediate results after the removal of the plaster in full supination were good but all but one have had recurrence of the pronation deformity *Green* (1942) and *McCarroll* (1949) report somewhat better results but the length of their observation time are not known *Phelps* (1957) has found as a late result of soft tissue surgery for pronation contractures recurrences in all cases he advocates the use of a d rotation osteotomy on the radius as it gives a lasting correction However we do not find such an operation indicated as the pro-

nated position is to be preferred to the danger of a permanent supination contracture

ad 2) To improve upon the flexion contracture of the wrist simple tenotomies on the wrist flexors were of no value in our hands as we operated on only rather severer contractures In a few cases of mild flexion contractures of the wrist *Swanson* (1960) did such tenotomy or elongation of the wrist flexors although in most instances he carried out the transposition of these muscles dorsally—in a similar way as described below—or performed a fusion of the wrist To abolish flexion contracture of the wrist we transferred the strong and shortened wrist flexors either to the radial wrist extensors the long thumb abductor and/or to the long finger extensors—in order not only to correct the flexion contracture of the wrist but also if indicated to improve upon a pronation contracture or weakened finger extensors These procedures have been of little value and confirmation of this opinion is to be found in the literature F inst *Heyman* (1939) reports bad results with all these procedures when applying transposition of the wrist flexors to the finger extensors he has even produced severe secondary contractures with ulnar deviation of the hand

Green & Banks (1962) on the other hand report improvement of dorsi flexion of the wrist with additional improvement of supination by transposing the flexor carpi ulnaris to one of the radial wrist extensors —However they only obtain improvement on a very selective indication milder cases with good control of finger movements

The best results we have had in correcting the marked flexion deformity of the wrist and improving function of the hand followed a wrist fusion either with or without additional transposition of the flexors as above outlined and there is full confirmation in the literature of this opinion

A fusion of the wrist is never done unless there is some active power in the finger flexors Always preoperatively we splint the wrist in neutral—*or in slight volar flexion*[1] *passive stretching* or the finger flexors and exercises of the finger extensors are pursued at the same time In some instances extension of the fingers and active opening of the hand are only possible by simultaneous maximal volar flexion in the wrist A wrist fusion can result in a permanent clenched fist although the fusion may have been performed in a neutral position and activation of the finger extensors in addition performed by the best possible tendon transpositions

[1] See foot note page 447



Fig 1

The technique we use for the fusion shortens the lengths of the bones The distal end of the ulna is resected and the radio-carpal fusion is performed very simply by forcing the tapered end of the radius down into a frontal slide in the carpal bones Fusion has always occurred (Fig 1) By this shortening of the bones the long finger flexors and extensors are relatively elongated and this sometimes produces as fair a muscle balance as one can hope for Therefore the wrist flexors are not always employed to reinforce extension of the fingers

It is worth while mentioning that a procedure used by *White* (1962) —a muscle sliding operation such as described by *Scaglietti* for use on Volksmann s contractures done before the wrist fusion—has the similar aim of elongating the spastic flexors and diminishing the spastic pull

One should be very careful to reinforce the finger extensors We do it with the help of the ulnar wrist flexor—using the radial wrist flexor for the purpose of improving function of the thumb—a topic to be dealt with later

It can be very difficult to estimate in a spastic dystonic hand the power of the profundi and the sublimes And I believe this—in addition to the dysfunction inherent in the disease—is the reason why reports in the literature are controversial

In a few of our cases with transposition of the ulnar wrist flexor to all finger extensors including the thumb we have had some slight improvement but not in all However we have had no severe overcorrection of the muscle balance on the selective indications employed *Heyman* (1939) reports no improvement of finger extension activation by use of both wrist flexors and *Goldner* (1955) has produced overcorrtion with the use of one wrist flexor which had produced a swan

deformity he had to reoperate upon secondarily. *Swanson* (1960) also uses a wrist flexor for extensor activation but prefers to use the sublimes if the profundi are of sufficient power; he then also performs a tenodesis of the proximal interphalangeal joints using the remnants of the sublimes tendons in order to prevent any secondary deformity by the reinforcement. We have had no personal experience with this suggestion by *Swanson* but theoretically there is a good argument for using it: he is imploying a deforming factor for the correction—an established principle in work with paralytic deformities. The argument against it is what has already been stressed: the difficulties in estimating the finger flexors power in a spastic dystonic hand.

It should perhaps be mentioned that *Swanson* in some of the milder cases he finds indication to operate upon has used a wrist extensor for the finger extension reinforcement and left a wrist flexor intact so that the effect is one of a tenodesis.

Goldner (1955) like *Swanson* uses the sublimes for finger extension activation but in a rather fanciful way: he reinforces the extensors to the third, fourth and fifth finger by the ulnar wrist flexor but uses a split sublimes tendon from the fourth or fifth finger to reinforce extension of the second finger: one snip subcutaneously to the tendon of the first dorsal interosseous muscle, the other through the lumbrical canal to the extensor aponeurosis. He might gain some abduction stability of the second finger—although I have never met with a case in need of it, but the recommendation to use the sublimis of the fifth finger does not appeal to me as this tendon usually is very tiny with not much power.

Before leaving the subject of extrinsic imbalance of the fingers and in order to make the quotation from the literature complete I shall mention that *Goldner* seems to have seen cases with hyperextension deformities of the distal interphalangeal joints, which needed repair by reinforcing the profundi by the sublimes using an en bloc suture of all tendons. *These deformities I would think were very rare in the spastic hand.* *Goldner* also has found indication for fusing the proximal interphalangeal joints of the fingers for severe flexion deformities of these joints. We have not tackled so severe cases in this manner—only done a wrist fusion with reinforcement of the digital extensors gaining cosmetic improvement but not always functional improvement of the fingers.

We have tried in a few instances to repair the intrinsic plus deformity or the swan neck deformity after the manner described by *Swanson*

(1960) His analysis of the extensor mechanism in the spastic hand is excellent and I believe he is right in supposing that it is the spastic pull of the extrinsic muscles and not spasticity in the intrinsic muscles which is dominant in producing the deformity *Swanson*s remedy is very simple a tenodesis of the sublimes anchoring these tendons to the proximal phalanges with the proximal interphalangeal joints in some flexion without severing the tendons But in our hands the results—very promising to begin with—are not very good there is an obvious tendency to recurrence of the hyperextension deformity —When the profundi are weak and the sublimes cannot be spared *Swanson* employs the usual anterior capsulorhaphia

Burman (1938) and *Goldner* (1955) cut the lateral bands as they are of the opinion that spasticity in the intrinsic muscles is responsible for the deformity It is difficult from their articles to estimate their results

In finishing the description of the various methods employed for the intrinsic plus deformity wish to mention that *Swanson* recommends the usual flexion osteotomy on the metacarpals—the procedure in use for the rheumatoid hand—when volar dislocation of the fingers has taken place however I have never seen such a deformity in a spastic hand

In concluding the discussion of the swan neck deformity I should like to say that I am somewhat amazed at all the work done in repairing it In my opinion this deformity is mostly a cosmetic problem and I do not believe a successful repair adds much to the function of the clumsy dystonic spastic hand

ad 3) When the thumb is permanently adducted or lying in the palm of the hand making an active opening of the hand for grip impossible the first thing we do—when a wrist arthrodesis is called for which usually is the case—is to perform the radio-carpal arthrodesis in marked ulnar deviation[1] as recommended by *Cooper* (1952) when the thumb cannot be brought away from the hand the hand can be brought away from the thumb (Fig 1) In some instances this is helpful but far from always Then the tendon of the long extensor of the thumb is cut and rerouted in a radio volar direction and the radial wrist flexor

[1] This position is chosen primarily to relax the spastic over pull of the finger flexor But as we fuse the wrist not only in neutral between flexion and extension but also in ulnar deviation we obtain the wrist position for "power grip" (*Napier*) The "precision grip" has the wrist in dorsiflexion and in neutral between radial and ulnar deviation Our aim must in most instances be the "powerful grip" as improvement by surgery of finer movements is seldom possible in the spastic hand in which stereognosis apart from the motor impairment—often is poor

is transposed to it a procedure also used with advantage by *Goldner* and *Swanson* This will lead to hyperextension deformity of the meta carpo phalangeal joint of the thumb (Fig 1) and a fusion of this joint is always performed *Swanson* also does this fusion as a routine pro cedure but *Goldner* not always We usually do a myotenotomy of the first dosal interosseous muscle and of the adductor pollicis at the same time as the fusion—a procedure also employed by *Goldner* and in a modified manner by *Burman, Leo Meyer* (1938) and *Swanson*

Goldner sometimes adds the usual sublimis transfer to induce opposition power to the thumb a procedure we do not think we have yet had any indication to employ in a spastic hand

If the above procedures we use—reinforcement of abduction pull by the mentioned tendon transfer in combination with fusion of the meta carpo phalangeal joint—do not bring the thumb sufficiently far out from the palm we have in a single instance also fused the carpometa carpal joint as recommended by *Steindler* (1952) also employed by *Swanson* There is an additional intermetacarpal osteoplastic proce dure as recommended by *Phelps* (1957) and *Swanson* which I am sure is worth using in very bad cases although the thumb is converted to a rigid strut we have not tackled such a severe case by this triple procedure

In one case a severe flexion deformity of the interphalangeal joint occurred after the above mentioned operations and we did an elonga tion of the long flexor to the thumb with a satisfactory result This has also been performed by *Swanson*

CONCLUSIONS

To answer the question under consideration whether we have been too conservative and omitted the use of some valuable additional pro cedures suggested in the literature I think it is appropriate to state that the interventions we have employed the frequency with which we have employed them and the results we have obtained by them display an approach to surgery of the spastic hand which is in accordance with many of the authors views

A few have employed some procedures we have not found use for the reason probably in most instances being that they also wanted to improve upon a spastic hand not very badly damaged by the Cerebral Palsy However many of these various procedures have been used in series of cases not large enough to draw any definite conclusions with

regard to the results which can be expected Further some overcorrections have been seen making reoperation necessary

I personally would only add to my mental armament of *possible* procedures to apply upon the spastic hand the use of the sublimes for finger extension reinforcement (*Swanson*) and perhaps also the use of the conventional sublimis transfer for opposition of the paralytic thumb (*Goldner*) on a very selected indication finally the use also in the very bad hand of the triple arthrodesis procedure on the thumb and of fusion of proximal interphalangeal joints when these are permanently flexed

It is to a large degree a matter of temperament to what extent one judges an operation on the spastic hand to be indicated I still would hesitate to try to improve by surgery a spastic hand which has some skilful abilities the only possible exception to this rule is the employment of the flexor carpi ulnaris transposition to the radial wrist extensors to improve upon a moderate flexion—pronation contracture in a hand with fairly good finger control I think the main indication for surgery is the rather badly damaged hand which at the utmost can be considered a supporting hand But then I feel that such a hand can be improved often more than expected It is not possible to convert in into a skilful hand it will still only be a "supporting hand but a better one

Whatever kind of temperamental attitude towards surgery of the hand one adopts I believe the following statements are valuable to keep in mind

Fusion of joints is most reliable because results are fairly predictable by preliminary use of adequate splinting during training

Tendon transpositions alone are to a large extent unreliable and over correction is a danger Nevertheless their use is sometimes indicated If used however the tendon transfers should preferably be combined with joint stabilization—arthrodeses or tenodeses—in order to govern and regulate the dynamic of the reinforcement

Myotenotomies and elongation of tendons can additionally be of some use but one must realise that improvement is often lost later if other stabilizing or balancing procedures are not simultaneously employed

In finishing this report I would like once again to stress that only procedures with the most elementary objectives yield consistently fair results Remember that in Cerebral Palsy the normal interrelated functions of contiguous articulations in the fingers and hand are profoundly affected and that whatever one does one can never obtain a cur

the utmost some improvement in a simple specific function to a badly damaged hand.

SUMMARY

Seventeen hands involving 54 individual operations from the Clinic for Cerebral Palsy at the Orthopaedic Hospital in Copenhagen are reported upon.—On all the hands more than one individual operation was performed as a combined operation and often several combined operations were performed at the same operative session or with some months interval. The results are compared with results in the literature. Further some suggestions from the literature to improve function of the spastic hand by surgery not personally employed are discussed. *On the basis of a critical analysis of the procedures which we used at* our clinic and those rather few additional suggestions in the literature it is concluded that the fairly moderate attitude towards surgery of the spastic hand which we—and many others—have adopted is advantageous: only simple procedures with the most elementary objectives yield consistently good results. One must be very cautious in trying to improve by surgery the function of a spastic hand which has some skilful abilities. The indication for surgery is mainly the badly damaged spastic hand which at the utmost can be considered a supporting hand. But then such a hand can often be improved more than expected.

RESUME

Dix-sept mains comportant 54 operations individuelles effectuees a la Clinique de paralysie cerebrale de l'Hopital orthopedique de Copenhague font l'objet du rapport.

Sur toutes ces mains plus d'une operation individuelle a ete effectuee comme operation combinee, souvent plusieurs operations combinees ont ete pratiquees pendant la meme intervention ou a quelques mois d'intervalle. Le resultats sont compares a ceux de la litterature. Par ailleurs il est discute de certaines suggestions de la litterature pour ameliorer la fonction de la main spastique par une chirurgie qui n'a pas ete appliquee personnellement par l'auteur. Sur la base d'une ana*lyse critique des méthodes que nous employons* dans notre clinique et de quelques suggestions additionnelles tirees de la litterature il est conclu qu'une position plutot moderee quant a la chirurgie de la main spastique que nous – et beaucoup d'autres – avons adoptee est a la préferer: seules des methodes simples ayant l'objectif le plus elemen

laire donnent de bons resultats Il faut etre tres prudent quant aux tentatives d une amelioration par le moyen de la chirurgie de la fonction d une main spastique qui possede encore une certaine habilete L indication de l intervention chirurgicale doit etre principalement la main spastique fortement endommagee qui peut tout au plus etre con sideree comme une main de support Mais dans ce cas l etat d une telle main peut souvent etre ameliore plus que l on ne s y attendait

ZUSAMMENFASSUNG

Uber siebzehn Hände mit 34 Einzeloperationen aus der Klinik fur Cerebrallähmung des orthopädischen Krankenhauses in Kopenhagen wird berichtet An allen Handen wurde mehr als eine Einzeloperation in Form einer kombinierten Operation ausgefuhrt und oft wurden mehrere kombinierte Operationen in derselben Sitzung oder mit mehr monatlichem Intervall ausgefurt Die Ergebnisse werden mit den Ergeb nissen der Literatur verglichen Weiterhin werden einige Vorschläge aus der Literatur zur Verbesserung der Funktion der spastischen Hand mittels des chirurgischen Eingriffes die jedoch personlich nicht ver wendet wurden besprochen Auf Grund einer kritischen Analyse der Verfahren die wir an unserer Klinik anwenden und jenen ziemlich sparsamen Vorschlagen in der Literatur schliessen wir dass die ziem lich bescheidene Einstellung die wir gegenuber der Chirurgie der spas tischen Hand eingenommen haben vorteilhaft ist Nur einfaches Vor gehen mit elementarster Zielsetzung ergibt dauernd gute Resultate Bei dem Versuche die Funktion einer spastischen Hand die von vornherein eine gewisse Geschicklichkeit besitzt zu verbessern muss man sehr vor sichtig sein Operationsanzeige ist meist die schwer beschadigte spas tische Hand die hochstens als eine unterstutzende Hand angesehen wer den kann Aber solch eine Hand kann uber alle Erwartungen hinaus verbessert werden

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FUNCTIONAL CAPACITY AFTER HIP ARTHRODESIS

By

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The results obtained with arthroplasty having fallen short of expectations and there has been a tendency in recent years to prefer hip arthrodesis The various papers published on this operation appear to be concerned mainly with surgical methods and the frequency of bone healing rather than with loss of function and its causes In the present article an account is given of an analysis of the patient s functional capacity after the operation

MATERIAL AND METHODS

The study took the form of a follow up examination of 35 patients with a hip joint arthrodesis In connection with this examination radiographs were taken of 25 of the cases The age and sex distributions were as follows

	<40	40–49	50–59	60–69	>69	Total
Men	4	5	5	10	4	28
Women	1	1	1	2	–	7
Total	5	6	6	12	6	35

The follow up included a detailed case history and a careful enquiry into the patient s ability to perform various routine operations of everyday life A thorough clinical examination was also made the details of which have been reported in a previous issue of this journal together with the procedure for the X ray examination (*Ahlbäck & Lindahl* (1))

RESULTS

Radiographic healing—In 4 of the 25 patients undergoing radiographic examination in connection with the follow up there was pseudoarthrosis Healing was incomplete also in one of the 10 others that had been radiographed at an earlier stage Thus non union of the bone was found in altogether 5 of the 35 cases (14 per cent) All these

patients had pain in the affected hip when walking and when the joint was placed under load The pain was moderate however and considerably less severe than it had been before the operation Three out of 21 cases or 14 per cent with confirmed bony ankylosis of the hip felt pain in this region after effort it was of moderate intensity and usually appeared after 10–30 minutes walking The ankylosis in these cases was true with bone trabeculae bridging the former joint space but there were cyst like formations in or near the joint that might account for the pain None of the other cases had pain in the affected hip

Subjective assessment—All 35 patients expressed satisfaction with the operation and considered that it had been to their benefit Even those with pseudoarthrosis and some mobility and pain were of the opinion that the discomfort had been greatly alleviated and that this far outweighed the restriction of mobility Some of the patients considered that the hip might have been set in a better position but most of them had had no experience of any other and were therefore unable to express an opinion One patient whose hip had been fixed in slight abduction and almost full extension incurred a fracture of the subtrochanteric region of the same femur in a motor accident On healing the hip assumed a neutral position frontally and a flexion angle of 40 The patient stated that there had been an immense improvement and had much less discomfort in walking and sitting than before

Walking capacity—The ankylosis itself did not interfere with walking but in many cases the distance was restricted by pain in the knees or the mobile hip poor physical condition or corpulence In a primarily aesthetic assessment of the walk 10 were classed as good 10 as moderate and 15 as poor (29 29 and 42 per cent respectively) Six of the 35 or 17 per cent used one cane and two patients required two—chiefly because of pain in the mobile hip or the knees Walking in snow especially if it was deep was difficult or impossible for any of the patients particularly when the hip was set at a small angle of flexion

Sitting—This was graded as good moderate or poor and here too the distribution was 29 29 and 42 per cent but there was no exact correspondence between the walking and sitting capacity in the individual cases Nineteen of the 35 or 54 per cent were able to sit on ordinary chairs without much trouble Seventeen of the 35 or 49 per cent found difficulty in using an ordinary toilet stool and 9 of them (26 per cent) were greatly inconvenienced in this respect As a consequence they had to stand have specially raised seats made or have a grip fixed to wall Several patients could not get up from an ordinary toilet stool in one

case the patient had been obliged to remain seated in a public toilet for several hours. Twenty of the 35 patients, or 57 per cent, had difficulty in sitting in the cinema or theatre, which they therefore could not attend unless they could sit at the end of the row.

Bathing.—Twenty six of the 35 could get into and out of a bath, whereas the others (26 per cent) had to rely to some extent on help.

Swimming.—Of the patients that had previously been able to swim, 22 out of 27, or 81 per cent, were still able to do so. Most of them did the breast stroke but some could also do the crawl. Inability to swim after the operation was usually due to fear or lack of initiative.

Running.—Seventeen of the 35, or 49 per cent, were able to run, most of them only a short distance and not very fast. One of the patients could ski 30 km.

Driving.—Of the 20 patients that had been able to drive a car before the operation, 11 could still do so (55 per cent). Those that could not gave as their reason difficulty in sitting in the driver's seat and stiffness in the knees. A patient who had had his arthrodesis in his youth had been driving an ambulance for 30 years and had even carried loaded stretchers up 5 flights of stairs.

Dressing.—The operation in dressing that caused these patients most trouble was putting on their shoes and stockings; the difficulty was about the same in both cases and was worse on the stiff side. Only 7 of the 35 (20 per cent) could tie their laces; the others had help or used shoes with the laces already tied or ones with elastic tightening. The situation was much the same for stockings. Most of the patients used a cane or some other aid. Putting trousers on could also be troublesome and the patient usually relied on some device for pulling them up (a cane or special tongs). The other operations in dressing did not present appreciable difficulty.

Working capacity.—Seventeen out of the 35 patients had been able to continue with their occupation, which often involved quite heavy work (49 per cent). Light had changed to a lighter job, 7 had retired prematurely on account of illness, but only 3 of these because of the hip operation. Three had given up work on reaching retiring age, and 2 of these considered that they were still capable of working; the third was prevented by another illness. Thus only 3 out of the 35, or 9 per cent, were unable to work because of the arthrodesis.

Loaded leg (standing leg).—Twenty six of the 35 subjects always used the mobile leg as the standing or resting leg. Three used both legs alternately, and 6 used the stiff leg as the standing leg, in 4 cases of

viously because of pain on loading the mobile hip arising from osteo-arthritis Only 2 of 31 or 6 per cent, used the stiff hip as the resting leg from choice The position of the hip in these cases did not differ in any way that could explain the choice of the standing leg

Oedema of legs—In 12 out of the 35 cases there was oedema in one or both legs after the operation (34 per cent) In 6 it was considerable and usually accompanied by aching and a feeling of heaviness (17 per cent) The swelling was undoubtedly due to postoperative thrombosis and was usually bilateral When it affected only one side it was usually that of the stiff leg

Knee symptoms—Deterioration of the knee joint on the operated side with pain and stiffness had occurred in 15 out of 35 cases and more severely in 5 (43 and 14 per cent respectively) All could extend to 180 6 could not flex to more than 135 a further 10 could flex more than this Twenty four out of the 35 or 69 per cent could flex to 90 or more The pain usually corresponded in intensity to the degree of the flexion defect

Low back symptoms—Twenty one out of the 35 patients had no back pain (60 per cent) Fourteen had mild pain 10 of them being uncertain whether it was associated with the stiff hip since it had usually been felt before the operation Only 4 stated that the back pain was linked with the operation (11 per cent) None of them found it severe These 4 cases all had an abduction position of the hip, but it was moderate Low back pain was usually accentuated by walking long distances

Symptoms from the mobile hip—Eight of the 35 patients had radiographic and/or clinical signs of osteo arthritis in the mobile hip (23 per cent) This was accompanied by more or less pronounced pain and stiffness in this hip and these were the patients that had most trouble in their daily routine

DISCUSSION

It is evident from the follow up study that a patient with a hip arthrodesis in a suitable position who had no pain in the back or mobile hip and who had not had post operative complications in the form of pain or stiffness in the knee thrombosis or corpulence could manage his daily routine without trouble He could even perform heavy work walk and sit as he wished and indulge in sport within reasonable limits Even the patients that were incapacitated in any of the above ways were satisfied with their arthrodesis since in any case they had been relieved of their aches and pains in one part of the body

Typical and common complications after hip arthrodesis are thrombosis stiffness in the knee and increase in weight Although complication cannot be avoided completely it should be possible with appropriate techniques to keep them within such bounds that they do not in themselves constitute a contraindication to the operation

As regards the position of the hip *Ahlbäck & Lindahl* (1) have expressed their views on the position that provides the best function This position may be questioned but then accurate methods should be used for measuring the position of the hip and for establishing the chosen position at the operation It is obvious that the patient himself cannot be expected to form an opinion on which position is the best

The presence of low back pain or stiffness in the back before the operation might be regarded as a contraindication for arthrodesis but this must be judged from case to case Persistence of back pain after an arthrodesis means that the walking is difficult and painful but on the other hand the low incidence of such symptoms in the long run suggests that moderate back pain need not constitute a contraindication Some authors (*Fox* (2)) consider that low back pain is in fact an indication for arthrodesis since it will often be less severe after the operation The stiffness too seems to decrease (*Ahlbäck & Lindahl* (1)) So long as we cannot solve the patients hip problems in any other way—and the problem is a difficult one—low back pain if not too severe is not a contraindication for an arthrodesis

As regards the mobile hip osteo-arthritis with pain also on this side invariably causes the patient considerable trouble and these cases are the most difficult ones to treat Hence if there is a conceivable alternative to arthrodesis it should be chosen On the other hand the alternatives in the case of bilateral osteo-arthritis are few and one must of course decide whether one s result with arthroplasty is preferable to an arthrodesis In fact the patients in the present series who had pain in the mobile hip were satisfied after an arthrodesis had been performed since it meant that at least on one side a marked alleviation of the pain was obtained

Even though a sound and mobile hip is of course preferable an arthrodesis is an excellent operation if the position is ideal no complications develop and the back and mobile hip present no problem Low back pain prejudices the results and pain in the mobile hip constitutes a relative contraindication

SUMMARY

The author followed up 35 patients who had undergone a hip arthrodesis operation In 14 per cent there was no healing of the bone Nonetheless all were satisfied with the operation because it had resulted in alleviation of the pain at least on one side The ability of the patient to manage routine operations in daily life and his fitness for work are dealt with It is concluded that so long as complications such as pseudoarthrosis knee pain and thrombosis can be avoided a hip arthrodesis with an ideal position is an excellent operation in cases in which there is no trouble from the back or the mobile hip

RÉSUMÉ

L'auteur a réexaminé 35 malades ayant subi une opération d'arthrodèse de la hanche *Dans 14 pour cent des cas il n'y avait pas de soudure* de l'os Néanmoins tous les malades étaient satisfaits de l'opération parce qu'elle avait apporté un soulagement aux douleurs tout au moins d'un côté Cela était lié aussi à la capacité du malade de vaquer à des occupations routinières dans la vie de tous les jours et à son aptitude au travail Il est conclu qu'aussi longtemps que l'on peut éviter des complications telles que la pseudarthrose les douleurs du genou et la thrombose l'arthrodèse de la hanche dans une position idéale est une excellente opération dans les cas où il n'y a pas de troubles dans le dos ou la hanche mobile

ZUSAMMENFASSUNG

Der Verfasser hat 35 Patienten nachuntersucht bei denen eine Arthrodese der Hüfte ausgeführt worden war In 14 Prozent war keine knöcherne Heilung vorhanden Dennoch waren alle mit der Operation zufrieden da sie eine Erleichterung der Schmerzen wenigstens auf einer Seite zur Folge hatte Die Fähigkeit des Patienten das tägliche Leben nach Routineoperationen zu meistern und seine Arbeitsfähigkeit werden erläutert Man schliesst dass eine Hüftarthrodese in idealer Stellung eine ausgezeichnete Operation in Fällen ist in denen keine Beschwerden von seiten des Rückens oder der bewegliche Hüfte bestehen wenn Komplikationen wie Pseudarthrose Knieschmerzen oder Thrombose vermieden werden können

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From the Orthopaedic Clinic, Borås (Head: Docent Folke Ståhl)

IMMEDIATE POSTOPERATIVE FITTING OF PROSTHESIS FOR LOWER LIMB

By

BERTIL KNUTSSON and FOLKE STÅHL

According to conventional principles of treatment, amputees are not fitted with an artificial limb until after the oedema has subsided and the stump has healed and assumed a more definitive shape. This procedure implies a fairly long interval between amputation and measurement for a prosthesis—between 6–8 weeks in children and several months in elderly patients (see e.g. *Slocum*). To this must be added the time necessary for making the prosthesis before the patient can begin to learn to walk with it. Such a long period of inactivity results in impairment of the patient's general condition, vitality, muscle control and cerebral co-ordination, and tends to increase the mental reaction of the patient, who may then regard himself as a cripple for life and thereby delay rehabilitation. Professor *Weiss* of Poland has demonstrated a film illustrating amputees in whom an artificial limb was fitted under anaesthesia and who started to walk with it a few days after the operation. This treatment appealed to us since it promised considerable shortening of convalescence and a much earlier return of the patient to a gainful occupation.

During the last year the following therapeutic principles in cases of amputation have been adopted at the department of orthopaedics, Borås general hospital.

The length of the leg and the size of the foot are measured before operation. The limb is amputated in the usual way under general anaesthesia. Rubber tube drainage. Some hours after the patient has awakened from the anaesthesia he is allowed to sit up in a chair. The following morning the drain is removed and a plaster casting is made of the stump wrapped in as little gauze as possible. The casting is then filled. The narrower end of the mould thereby obtained is wrapped in a 1–1.5 cm thick layer of rubber sponge. A casting is then made of the

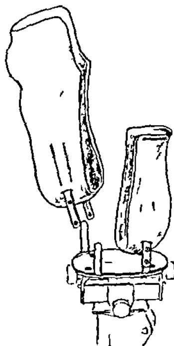


Fig 1

model with the rubber Four steels are incorporated in the casting When the casting has set it is slit up and removed from the model The 4 steels are afterwards fastened in Hosmer s adjustable leg which is in turn fastened in the foot (Fig 1) In the afternoon of the day after the operation the prosthesis is applied and the patient begins to walk with it

For obvious reasons the procedure described will not allow the use of an open cylindrical prosthesis because the upward pull of the soft tissue during weight bearing would prevent rapid healing Therefore a closed type of socket must be used with a soft elastic bottom The weight should not be taken solely on the end of the stump but be distributed as evenly as possible over the entire surface of the latter A contact socket of this shape probably stimulates the local circulation by its pumping effect on the stump at every step an effect that presumably accelerates healing From the first day on the patient is given Tanderil Tablets This together with training to walk with the prosthesis and regular bandaging of the stump at night results in rapid regression of the oedema In fact within as short a period as 3–4 days the first socket may be too wide and must be replaced by a new one

A second socket can usually be worn for about a week a third socket for 2–3–4 weeks after which the patient may be fitted with a permanent prosthesis The change of temporary sockets provides a possibility of improving the shape of the stump from a functional point of view particularly in cases of above knee amputation Moreover the patient is only too pleased to be fitted with a permanent prosthesis because it is much lighter than the temporary one We have so far treated 15 patients in this way

1 A male aged 17 Laceration BK amputation
2 Male aged 19 Osteogenic sarcoma AK amputation
3 Female aged 29 Chronic osteitis with recurrent fistulae Previous amputation of metatarsal BK amputation
4 Male aged 82 Arteriosclerotic gangrene BK amputation
5 Male aged 33 Laceration BK amputation
6 Female aged 69 Embolism AK amputation
7 Male aged 65 Arteriosclerotic gangrene BK amputation
8 Female aged 16 Congenital defect BK amputation
9 Female aged 70 Diabetic gangrene AK amputation
10 Male aged 76 Diabetic gangrene BK amputation
11 Female aged 66 Fibrosarcoma BK amputation
12 Male aged 19 Laceration BK amputation
13 Male aged 62 Tumor cutis BK amputation
14 Male aged 76 Arteriosclerotic gangrene AK amputation
15 Male aged 47 Synovialoma BK amputation

In all 15 cases the postoperative course was uneventful The early ambulation caused no difficulties and the patients soon learned how to walk with the prosthesis The stumps healed in a normal way and shrank very soon This early mobilisation and training of the patients in the use of the prosthesis resulted in a shortening of the average number of hospital days—average 41 9 days from the amputation to the day when the patient leaves the hospital with the definite prosthesis —and also decreased the risk of complications due to long rest in bed The patients were able to return to a gainful occupation sooner than otherwise and the much feared long waiting time for the prosthesis was avoided Moreover since there is no period of inactivity between the operation and the application of a permanent prosthesis there is only a limited weakening of physiological function While patients treated by conventional principles are obliged to lie and sit idle at home with the risk of becoming fat and debilitated when waiting for their



Fig 2 AK amputation
2 days after the operation



Fig 3 BK amputation
3 days after the operation

permanent prosthesis those treated with an immediate temporary prosthesis become fitter and fitter from the very day after the operation It is also easier for the patient to learn how to walk with an immediate prosthesis because he has not had time to "forget how to walk In addition from the very beginning the patient has the feeling that something is being done for him This has a favourable psychologic effect which helps to prevent the idea of his being a cripple becoming so deep rooted in his consciousness as when he is forced to lie around idle waiting for a prosthesis and wondering what his artificial limb will be like and how it will function

Immediate temporary prosthesis can of course only be applied to patients who are able to walk at least with a stick before the operation

Judging from the observations made in the present series the method is recommendable in properly selected cases The only drawback of such treatment is that the changing of the temporary sockets can place an extra burden on an already overburdened workshop But this disadvantage is more than outweighed by the obvious advantages offered by the method

SUMMARY

The authors report a method of providing amputees with a temporary prosthesis directly following the amputation Walking exercises *with prosthesis* begin as early as the day after operation The first 15 cases are reported all with good results The procedure is recommended since the period of rehabilitation is considerably shortened

RESUME

Les auteurs communiquent une methode consistant a munir les malades amputes de jambes d une prothese provisoire immediatement apres l amputation Les exercises de marche *avec la prothese* commencent dejà le jour qui suit l operation Il est rendu compte des 15 premiers cas tous ayant donne un bon resultat Il est recommande d essayer ce procédé parce qu il reduit essentiellement la duree de la readaptation

ZUSAMMENFASSUNG

Die Verfasser teilten eine Methode mit die darin besteht dass man beinamputierte Patienten unmittelbar nach der Amputation mit einer Prothese versorgt Gehubungen mit der Prothese beginnen bereits am Tage nach der Operation *Über die ersten 15 Falle die alle ein gutes* Ergebnis aufwiesen wird berichtet Das Verfahren wird zur Über prufung anbefohlen da die Wiederherstellungszeit durch dasselbe be deutend verkurzt wird

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From the General Hospital, Bjorneborg, Finland

"THE PLANTA PEDIS SYMPTOM"—A NEW SYMPTOM OF COMPRESSION OF THE NERVE ROOT LV OR SI

By

HENRIK V. A. HEIKEL

During an attack of left sided sciatica with a typical SI syndrome I noticed in myself a symptom which I have not seen described in the literature (1–3). When I stepped on my left foot it felt as if under the capitulum mtII or mtIII there was a nail or a small stone in my shoe. This symptom disappeared along with the other symptoms of root compression as a result of complete bed rest. It left no permanent change. Because of this observation I have since looked for a similar symptom in my patients and noted its relation to other symptoms and to operative findings. In the following I shall relate my observations and try to explain the mechanism of origin of this symptom. I have called the symptom and its variations the planta pedis symptom.

MATERIAL

The planta pedis symptom was found in 13 patients with the sciatic syndrome, in 10 cases on the left and 3 on the right side. 8 of the patients were men with an average age of 41 years and 5 women with an average age of 43 years.

PAST HISTORY

11 patients had complained of sacral symptoms. 7 patients had had at least one previous attack of sciatica on the same side, one had had sciatica on the contralateral side and one had had a bilaterally positive Lasegue sign but no symptoms of prolapse.

SYMPTOMS

There had been acute onset of pain in 4 cases (in 2 cases when the patient bent forward to tie his shoe-laces), in the remaining cases the onset had been gradual.

The predominating symptom was radiating pain in the leg in 12 cases and in 1 case a sensation of numbness in the leg

Other subjective symptoms were Pain in the leg on coughing and sneezing 5 cases the same in the back 1 case Numbness 2 cases Pricking as by ants in the contralateral foot 1 case Trembling in the muscles of the calf of the leg 1 case

OBJECTIVE SYMPTOMS

Positive Lasegue sign 11 cases (in 4 cases at 30 to 35 in 3 at 40 to 45 in 2 at 50 to 55 in 2 at 70 to 75)

Crossed Lasegue 5 cases (In one patient both the Lasegue sign and the crossed Lasegue had become negative before the onset of the planta pedis symptom)

Weak patellar reflex 1 case (this patient had been confined to bed for two months before visiting a doctor and he had severe atrophy of the muscles of the entire leg)

Weakened extension of the great toe 7 cases 3 of which were mild

Weakened Achilles tendon reflex 10 cases (the reflex was absent in 5 cases) In addition the Achilles tendon reflex was weakened on the contralateral side in 1 case

Reduced sensibility within the LV dermatome certain in one and uncertain in 3 cases

Reduced sensibility within the SI dermatome certain in 6 and uncertain in 2 cases

Reduction of the sensibility in a wedge shaped area from the middle of the instep to the plantar side of the second to the fourth toe 2 cases

Reduced tonus in the gluteal muscles (2) 3 cases

Fallen transverse arch 1 case

CLINICAL DIAGNOSIS

On the basis of the subjective and objective symptoms the following diagnoses were made

1 Compression of the LV root 1 case

2 Compression of the LV and SI roots 6 cases (in 2 cases compression of the root LV was considered predominant in 4 cases compression of the SI root)

3 Compression of the SI root 5 cases

4 Sciatica with no indication as to the compressed root 1 case with acute onset which had been examined once only when no certain symptoms of prolapse could be detected

The diagnosis was verified by myelography and subsequent operation in 2 and by operation alone in 5 cases Because the prolapse symptoms from the SI root predominated the disc LV/SI in one case was first explored but the prolapse was situated at the LIV/LV level In those cases in which operation was not considered to be indicated myelography was not carried out

In 3 of the operated cases a prolapse of the LV/SI disc compressed the root SI In 3 cases a medial prolapse of the disc LIV/LV compressed the root LV and might also have irritated the root SI In 1 case the LV root was compressed by a prolapse of the disc LIV/LV situated laterally to the root It is thus evident that the planta pedis symptom may occur in both isolated compression of either the LV or the SI root and in simultaneous compression of both roots

The planta pedis symptom did not occur (or was not observed?) until after the operation in 2 cases whilst in 2 other cases the symptom was aggravated during the postoperative stage The probable reason for this is that during the operation the root was subject to pressure or stretching but the possibility of a prolapse at another level than that removed at operation whether subsequently occurring or overlooked during the operation cannot be excluded I shall briefly relate these cases

1 (P R A L Bjorneborg General Hospital 5394/62) LV + SI syndrome with weakened extension of the great toe and Achilles tendon reflex and pain radiating to the lateral side of the calf of the leg Pressure on the intervertebral space LIV LV during operation produced radiating pain at the same site In this space there was a large medially situated prolapse Postoperatively the area under the capitulum mtII–III felt thick Pain was sometimes felt in this area Four months after the operation the Achilles tendon reflex was negative otherwise the status was normal

2 (V T J Orthopaedic Hospital of the Invalid Foundation 2940/64) SI syndrome with absent Achilles tendon reflex Myelography Somewhat uncertain prolapse to the left at the LV/SI level Operative finding The SI root was adherent to a low dried up prolapse of the disc LV/SI and the lower edge of the vertebra LV was prominent Postoperatively there was a slightly weakened extension of the left great toe the sensibility under the arch and the capituli mtII–III was reduced it feels like stepping on something soft

3 (J H Bjorneborg General Hospital 5373/63) LV + SI syndrome with reduced extension of the great toe and weakened Achilles tendon reflex Reduced sensibility in the three lateral toes Medially of the root LV in the space LIV/LV a rather large prolapse was found Postoperatively the pain disappeared but the foot felt weak and

the patient reported that it felt like stepping on a stone under the capitulum mtII III" and remembered that he had had the same feeling earlier although less pronounced When tip-toeing the patient showed a tendency to varus position in the ankle there was reduced sensibility in the LV and SI dermatomes Otherwise the condition was as before

4 (K J Bjorneborg General Hospital 5036 64) SI syndrome with weakened Achilles tendon reflex and reduction of the sensibility within the SI dermatome At operation the LV/SI space was explored and found intact, the SI root being insensitive to pressure Pressure on the root LV produced pain within the same area as the spontaneous pain Medially of the root a large prolapse of the disc LIV/LV was found Postoperatively the pain disappeared the foot felt somewhat weak and there was a tendency to sprain in a varus direction The patient remembered that since his first attack of sciatica 12 years earlier he had had a hard corn under the capitulum mtIII It became tender after the operation and he noticed increased sensibility under the foot The Achilles tendon reflex was weakened the extension of the great toe was insignificantly weakened and there was reduced sensibility within the SI dermatome

The planta pedis symptom is composed of a reduction of the sensibility and a pain component These may occur together or separately It was decribeed by 13 patients as

1 Pain under the capitulum mtII–III 9 cases In 7 of these pain was the predominating symptom In 3 cases compression of LV and in 1 case of SI was operatively demonstrated and in the other cases a clinical diagnosis of compression of LV was made in 1 case of (LV?) + SI in 1 case of SI in 2 cases (and in 1 case uncertain root compression)

2 Fullness "a cushion or "a fold in the stocking under the capitulum mtII–III 5 cases

In one of these cases compression of LV was operatively demonstrated whilst in the other cases compression of LV + SI was clinically diagnosed in two cases and compression of SI in one case

3 Loss of feeling under the middle of the anterior part of the arch of the foot 4 cases In 2 of these compression of SI was operatively verified while in 2 cases the same diagnosis was made clinically

4 A feeling as if "a thread had been tightened around the second and third toes 1 case The clinical diagnosis in this case was compression of SI

DISCUSSION

The variations of the planta pedis symptom are probably a result of functional disturbance of nerve fibres from the roots of LV and SI passing through the medial and lateral plantar nerves The lack of

sensibility is an expression of disturbed sensory function The feeling of fullness is probably also a result of the sensory disturbance possibly combined with an increased stress on the capituli mtII–III This increased stress must be the cause of the pain component and is itself the result of the falling of the transverse arch The falling of the arch is a consequence of the weakening of the adductor hallucis muscle which runs transversely under the metatarsal bones and which is innervated by the segments SI–SII The stress on the capituli mtII–III is probably further increased if the toes owing to weakened flexion in the metatarsophalangeal joint cannot take over some of the weight bearing This happens if there is weakening of the interosseal muscles innervated from the segments SI–SII which acting in concert produce plantar flexion of the phalanges in question and extend the interphalangeal joints The strength of the plantar flexion of the toes however depends *on the long and short flexors of the toes which are innervated from the* segments LV–SI A weakening of the plantar flexion of the first metatarsal bone (when the musculus fibularis longus innervated from the segments LV–SI is weakened) adds further to the stress on mt II and III

It is thus possible to trace the principal components of the planta pedis symptom to a disturbance of the function of the roots LV and SI a conclusion which is in agreement with the other clinical symptoms and with the operative findings in the operatively treated cases

The symptom is not a common one and since it may evidently occur as a result of compression of two different roots LV and SI it is of little significance as an aid to diagnosing the level of the lesion It is however an additional factor in the symptomatology of root compression

SUMMARY

A new symptom called the planta pedis symptom was observed in 13 patients with the sciatic syndrome On the basis of the subjective symptoms and objective signs a diagnosis of compression of the LV or the SI root (or both) was made and in 7 patients the diagnosis was verified by operative findings The symptom is composed of pain under the 2nd and 3rd metatarsal heads and (or) reduction of the sensibility with fullness of the corresponding plantar area

The pain component is probably the result of the falling of the transverse arch caused by the weakening of the adductor hallucis muscle This muscle is innervated by the segments SI and SII The plantar

surface under the metatarsal heads is innervated with sensory fibers from the segments LV and SI It is thus possible to trace the planta pedis symptom to a disturbance of the function of the roots LV and SI

RESUME

Un nouveau symptome appele «le symptome planta pedis» a ete observe chez 13 malades avec syndrome sciatique Sur la base des symptomes subjectifs et des signes objectifs un diagnostic de compression de la racine de la 5eme vertebre lombaire ou de la 1ere vertebre sacree (ou les deux) a ete pose Chez 7 malades le diagnostic a ete verifie par les trouvailles operatoires Le symptome se compose de douleurs sous l extrémite renflee des 2eme et 3eme metatarsiens et (ou) d une reduction de la sensibilite de la surface plantaire correspondante

Le composant de la douleur est probablement le resultat de l affaissement de l arc transversal cause par l affaiblissement du muscle adducteur hallucis Ce muscle est innerve par les segments sacres I et II La surfacee plantaire sous les metatarsiens est innervee par des fibres sensorielles des segments lombaire V et sacre I Il est donc possible de trouver la trace du symptome planta pedis a un trouble de la fonction des racines L V et S I

ZUSAMMENFASSUNG

Ein neues Symptom das planta pedis Symptom genannt wurde bei 13 Patienten mit Ischiassyndrom beobachtet Auf Grund der subjektiven Symptome und der objektiven Zeichen wurde die Diagnose einer Kompression der L5 oder S1 Wurzel (oder beider) gemacht und bei 7 Patienten wurde die Diagnose durch den operativen Befund bestatigt Das Symptom besteht in Schmerzen unter dem zweiten und dritten Metatarsalkopfchen und (oder) Herabsetzung der Sensibilitet mit Vollegefuhl der entsprechenden plantaren Flache

Die Schmerzkomponente ist wahrscheinlich auf das Herabsinken des Quergewolbes das infolge der Schwächung des m adductor hallucis entsteht zuruckzufuhren Dieser Muskel wird von den Segmenten S1 und S2 innerviert Die plantare Oberfläche unter den Mittelfusskopfchen wird mit sensiblen Fasern von den Segmenten L5 und S1 innerviert Es ist daher moglich das planta pedic symptom auf eine Storung der Funktion der Wurzeln L5 und S1 zuruckzufuhren

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